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Exploring The Complexity - Evaluating Root Canal Morphology In Permanent Mandibular Premolars: A Retrospective Cone Beam Computed Tomographic Analysis

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Abstract

The purpose of this study was to analyze the number of roots, root canals, and canal configurations in mandibular premolars (MPs)
using cone beam computed tomography (CBCT). A retrospective study was conducted on CBCT records of 70 patients. The scans were reviewed to assess the morphology of MPs, including the number of roots, canals, and their canal configurations. The relationship of these findings with bilateral symmetry and gender was also examined. In mandibular first premolars (MFPM), 91.4% were set up to have a single root, whereas in mandibular second premolars (MSPM), the circumstance of a single root was 97.8%. The majority of MFPM (71.4%) and MSPM (88.5%) displayed only one conduit. Vertucci's Type I configuration surfaced as the most common pattern, being present in 71.4%
of MFPM and 94.2% of MSPM. Analysis revealed no statistically significant association between gender and variations in root morphology, number, and configuration. MFPM demonstrated greater variation in canal number and morphology compared to MSPM, which more commonly presented with a single canal and Type I configuration. A high degree of bilateral similarity was observed, with no gender-based differences.

Keywords: Cone beam computed tomography; root canal morphology; root canal anatomy; mandibular premolars; anatomic variation

Introduction

The success of root canal treatment relies heavily on a comprehensive knowledge of root canal morphology and its internal variations. An accurate understanding of dental anatomy is a fundamental requirement for all clinical procedures, particularly endodontics, which focuses on the management of the tooth's internal structure. Inadequate awareness of canal morphology has been identified as the second leading cause of endodontic failure. (6) Among different teeth, mandibular premolars present some of the most complex and variable anatomical patterns, making them highly susceptible to endodontic complications (1–3) Several factors, including ethnicity, age, and gender, contribute to differences in the morphology and canal system of mandibular premolars. (4,5,10) Literature reports have documented a wide range of anatomical variations, such as the occurrence of multiple roots and diverse canal configurations in these teeth. (2,3,19–21) Over the years, a variety of techniques—such as canal staining, clearing and

sectioning of teeth, microscopic analysis, and evaluation of conventional radiographs—have been employed to study root canal anatomy. (9,11,13,14) However, these conventional methods have limitations. The introduction of advanced imaging modalities such as cone beam computed tomography (CBCT) and micro-computed tomography (micro-CT) has greatly enhanced accuracy by enabling three-dimensional assessment of root canal morphology. Unlike traditional radiographs, CBCT provides a non-invasive and precise tool for identifying anatomical complexities. (12,23)

The present study was designed to retrospectively assess the root canal anatomy and configurations of mandibular premolars using CBCT and to determine their relationship with bilateral symmetry and gender.

Materials And Methods

This retrospective observational study was initiated after obtaining approval from the Institutional Ethics Committee. CBCT scans were retrieved from the Department of Oral Medicine and Radiology, Baba Jaswant Singh Dental College, Hospital & Research Institute, Ludhiana, and the analysis was carried out in the Department of Conservative Dentistry and Endodontics.

A total of 280 mandibular premolars (140 first premolars and 140 second premolars) from 70 patients (41 males and 29 females) were included.

International Journal of Medical Science and Current Research | May-June 2018 | Vol 1 | Issue 1

Inclusion Criteria:

1. CBCT scans displaying the entire mandible with clearly visible root apices of premolars.
2. Balanced representation of right and left premolars.
3. Teeth with intact roots, without cracks or fractures.
4. Premolars free of posts or prior endodontic treatment.

Exclusion Criteria:

1. History of apicoectomy or periapical surgery.
2. Presence of odontogenic or non-odontogenic pathology.
3. Developmental anomalies, internal or external resorption, or pulp canal calcifications.
4. Previously treated endodontic cases.
5. Teeth with extensive restorations, posts, or root caries extending into the furcation region.
6. Poor-quality CBCT scans or those with imaging artifacts.

The final sample was assessed in Multi-Planar Reconstruction (MPR) mode of the CBCT software. Each premolar was examined in

axial, coronal, and sagittal planes, and the region of interest was triangulated for accuracy. The following parameters were evaluated:

a) Number of roots – single or multiple.

b) Number of canals – single or more than one.

c) Canal configuration – classified according to Vertucci's classification (1984) [16], which includes eight types of canal patterns.

Results

A total of 280 CBCT scans, comprising 140 mandibular first premolars and 140 mandibular second premolars, obtained from 70 patients (41 males and 29 females), were evaluated in this study.

1. Number of roots and their relation to gender and symmetry

Most MFPM were single-rooted (128 teeth, 91.4%), while two roots were identified in 8 cases (5.7%). No statistically significant difference was noted between males and females [Fig-1a,b]. In MSPM, a single root was present in 137 cases (97.8%), whereas two roots were observed in only 3 cases (2.14%) [Fig-2a,b]. Interestingly, three-rooted variations were detected exclusively in MFPM (4 cases, 2.8%) [Fig-1c]. Both MPs demonstrated a high degree of bilateral symmetry in terms of root number, with no evident influence of gender or side.

Volume 8, Issue 5; September-October 2025; Page No 165-170

Fig. 1 MFPM showing a) one, b) two, and c) three roots.

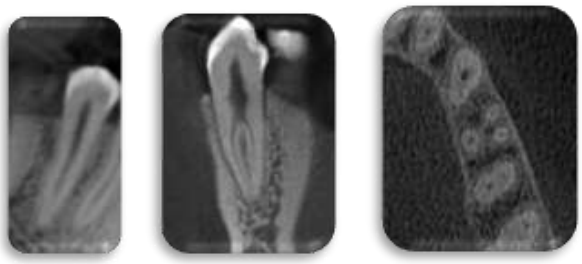
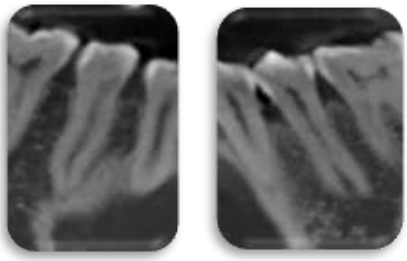


Fig. 2 MSPM showing a) one and b) two roots.



2. Number of canals and their relation to gender and symmetry

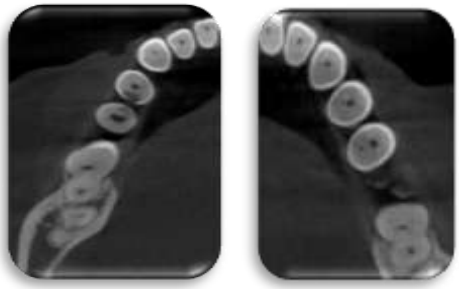
In mandibular first premolars, the majority exhibited a single canal (100 cases, 71.4%) [Fig-3a], while two canals were identified in 36 teeth (25.7%) [Fig-3b]. A limited number of first premolars (4 cases, 2.8%) exhibited three canals [Fig-3c], with no meaningful correlation to patient gender.

For mandibular second premolars, a single canal was the predominant finding (124 cases, 88.5%) [Fig-4a], followed by two canals in 16 cases (11.4%) [Fig-4b]. Similar to the first premolars, gender showed no significant influence on canal number.

Fig. 3 Mandibular First Premolar showing a) one, b) two and c) three canals.

Volume 8, Issue 5; September-October 2025; Page No 165-170

Fig. 4 Mandibular Second Premolar showing a) one and b) two canals.



3. Canal configuration and its relation to gender and symmetry

In mandibular first premolars, Type I canal configuration was the most frequently observed pattern (100 cases, 71.4%), followed by Type V (25 cases, 17.85%), both showing a significant bilateral symmetry but no gender-based differences [Fig-5a,b]. Type III configuration was found in 8 cases (5.7%) with a higher occurrence on the right side, while Type VIII (4 cases, 2.8%) and other less common configurations (3 cases, 2.14%) were also detected.

For mandibular second premolars, Type I configuration was predominant (132 cases, 94.2%), showing a higher prevalence compared to first premolars. This was followed by Type III (4 cases, 2.85%), both demonstrating significant bilateral symmetry but no association with gender [Fig-6a]. Type V was observed in 2 cases (1.42%) with a tendency to occur on the right side, again without significant gender predilection [Fig-6b].

Fig. 5 Mandibular First Premolar showing a) Type I, b) Type V Vertucci configuration.

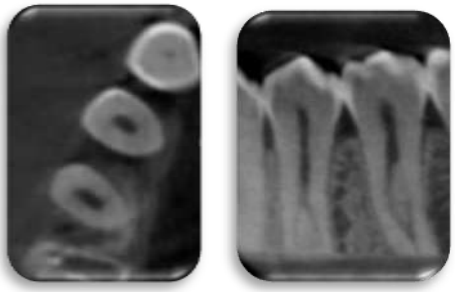
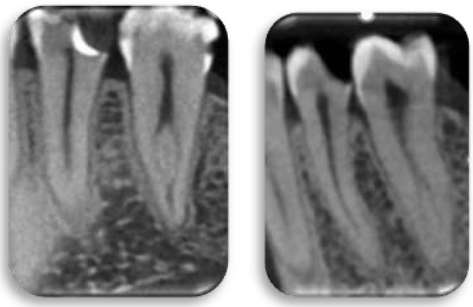


Fig. 6 Mandibular Second Premolar showing a) Type III, b) Type V Vertucci Classification.



Discussion

The tendency of mandibular premolars to exhibit anatomical variations in their root and canal morphology has been recognized as a significant factor contributing to endodontic failures. (19–22) Hence, a comprehensive understanding of this intricate system is essential for predictable clinical outcomes. In the present investigation, archived CBCT scans were employed to assess the root canal morphology of mandibular premolars, as this imaging

Volume 8, Issue 5; September-October 2025; Page No 165-170

modality offers high reproducibility and precise three-dimensional visualization, a finding corroborated by earlier research. (12,23)

In the current study, most mandibular first premolars were found to have a single root with a single canal, demonstrating bilateral symmetry. These results were consistent with findings reported in German and Western Chinese populations. (20)

Conversely, studies on Saudi, Iranian, and Kuwaiti populations have documented a higher prevalence of multiple roots. (21)

No significant association was observed between root/canal number and gender in our study. However, literature reveals variability in gender-based differences, which may be attributed to differences in sample size, ethnicity, and methodology across studies. (4,5)

Regarding canal configuration, a wide range of patterns was identified in mandibular first premolars. Type I was most frequently observed, followed by Type V, in agreement with previous reports. (1,2,22) Less common configurations such as Type III and Type VIII was also noted, though at a lower frequency, which contrasts with the findings of Kottoor J. et al. and Shetty A. et al. (22,23)While no gender predilection was seen in our study, some literature reviews, including that by Kottoor J. et al., suggest a higher prevalence of certain configurations in males (23).

In mandibular second premolars, the majority of teeth exhibited a single root with a single canal, aligning with studies by Bulut DG et al. and Bürklein S et al. (20). In contrast, Jordanian and Taiwanese-Chinese populations reported a higher frequency of multiple canals in second premolars (25). Such disparities may be explained by methodological variations and ethnic or geographical influences. In the present study, Type I and Type III were the most common configurations, which differs from reports

in South Indian populations where Type IV was more frequently observed (25). Overall, second premolars showed less variation in canal morphology, which was in agreement with studies on Western Chinese populations (20,24). A high degree of bilateral symmetry was observed in root number, canal number, and canal configurations in both first and second premolars, with no significant gender association. These results are in line with the findings of Alfawaz H. et al. and Corbella S. et al., who highlighted the clinical relevance of such symmetry in treatment planning (21).

An additional observation in this study was the occurrence of canal bifurcations, especially at the middle and apical thirds of the root. The complexity and prevalence of such variations emphasize the need for careful clinical and radiographic evaluation. The root canal system is highly dynamic, often presenting with bifurcations, rejoining, or apical terminations in multiple foramina.

Recognizing these variations is crucial for successful endodontic management. The diagnostic accuracy of CBCT makes it a valuable adjunct in identifying such complexities, aiding clinicians in decision-making and treatment execution. Future studies with larger sample sizes and diverse populations are recommended to further enrich the understanding of mandibular premolar morphology.

Conclusion

Mandibular first premolars showed greater variation in canal morphology, with a higher tendency for bifurcation and multiple apical foramina compared to second premolars. In second premolars, studies from Caucasian and Middle Eastern populations have reported higher percentages of multiple canals (14–17%). In the present study, Type I configuration was the most common in both first (71.4%) and second premolars (94.2%). Greater variation was noted in first premolars, though no significant gender association was identified. Ethnic differences appear to influence root and canal morphology across populations. Many cases demonstrated mid-root and apical canal splitting, which may contribute to treatment failures. Therefore, thorough preoperative radiographic assessment, supplemented with CBCT when required, is essential for accurate diagnosis and predictable treatment outcomes.

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Volume 8, Issue 5; September-October 2025; Page No 165-170

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Volume 8, Issue 5; September-October 2025; Page No 165-170