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C-Shaped Canal Configuration in Mandibular Premolars in The Indian Population using Cone Beam Computed Tomography: A Multicentric Study

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Abstract

Objective(s): The study aimed to assess the prevalence, bilateral occurrence and regional variations of C-shaped canal configurations and radicular grooves in first and second mandibular premolars among individuals from five different states of India using CBCT.

Material and Method: Ethically approved by the Ethics Committee of Maharashtra University of Health Sciences, this study included 207 CBCT scans from patients aged 14 and above with healthy, fully formed mandibular premolars. Using a Sirona Orthophos SL 3D CBCT machine and 3Diagnosys software, the scans were analyzed for the presence, position, and characteristics of C-shaped canals and radicular grooves. The Fan et al. (2004) classification system was used to categorize C-shaped canals.

Results: C-shaped canals were identified in 27.1% of first mandibular premolars and 2.7% of second mandibular premolars. The highest prevalence of C1 type canals was found in first premolars (25.8%). Bilateral C-shaped canals were observed in 6.8% of first premolars and 0.5% of second premolars. Radicular grooves were rare, found in only 0.72% of first premolars and none in second premolars. Regional variations were noted with the highest prevalence of C-shaped canals in first premolars from Maharashtra and the lowest in Gujarat.

Conclusion: C-shaped canal configurations are more prevalent in first mandibular premolars compared to second premolars with significant regional variations within India. The overall prevalence of radicular grooves was low. These findings highlight the need for careful CBCT analysis in endodontic treatment planning to manage the complexities of C- shaped canals.

Keywords: CBCT, C-shaped canal, Mandibular premolars, Regional variations.

Introduction

The success of endodontic treatment relies on a comprehensive understanding of the anatomy and morphology of teeth or root canals, along with their diverse variations. These diversifications encompass factors such as the presence of multiple canals, curved canals, and supernumerary roots. These anatomical variations may arise due to regional or ethnic distinctions, gender differences, the presence of grooves, accessory canals, and the positioning of teeth within the jaw.

The C-shaped canal configuration (CsCC) represents a distinctive alteration in the root canal system, characterized by an anatomical configuration resembling the letter "C."[1] This morphology entails the Hertwig's epithelial root sheath (HERS) failing to adhere to the buccal and lingual root surfaces, which is believed to be the main etiological factor in CsCC formation. In teeth with CsCC, the canal orifice typically presents [2] as a narrow ribbon-shaped single opening with an arc measuring at least 180°.[3]

Many studies have indicated that C-shaped canal configuration displays variations along the length of the root (see Figure 2). This variation can occur from the coronal to the apical third of the tooth root, making identification of C-shaped canals challenging. [4]

The internal anatomy of CsCC may exhibit fins, isthmuses, grooves, and dentin tissue surrounding the canal, complicating the processes of cleaning, shaping, and obturation. This complexity can increase the risk of endodontic failure. [5]

To facilitate identification and treatment, various classifications have been developed to categorize CsCC. [6,7] The most recent classification was proposed by Fan et al. in 2004.[7] Fan et al. provided a comprehensive description of C- shaped canals compared to Melton's classification, offering a more detailed insight into their characteristics and variations.[6]

Radiographically, identification of CsCC demands meticulous evaluation. Two-dimensional (2D) radiographs often result in superimposed images, which can impede the accurate assessment of C-shaped canal morphology and hinder the progression of root canal treatment, whereas cone-beam computed tomography (CBCT) imaging, on the other hand, is considered a suitable three-dimensional (3D) modality for evaluating root canal configuration. [8]

In the literature, majority of studies have focused on molars with only a few examining first and second premolars and their bilateral occurrence.[9] Also, there is a limited number of studies that have assessed the occurrence of radicular grooves, their depth and the level at which these grooves are present. Furthermore, previous studies have not thoroughly examined regional variations within specific populations. With the existing research gaps, the current study was designed to assess the prevalence and bilateral occurrence of CsCC, radicular grooves, and their depths, as well as regional variations concerning the first and second mandibular premolars among individuals from various states of India.

The study aims to achieve the following objectives: to identify and measure C-shaped canals in mandibular premolars using CBCT scans obtained from individuals representing five different states of India, to identify and measure radicular grooves in mandibular premolars using CBCT scans obtained from individuals representing five different states of India and to compare the occurrence of bilateral C-shaped canal configurations in both mandibular premolars using CBCT scans.

Materials and Methods

A retrospective, cross-sectional, observational study was conducted after obtaining approval from Institutional Ethical Committee. Sample size calculated was a total of 207 CBCT scans presenting mandibular premolars were obtained from private CBCT centers of five states of India.

According to study by Chen YC et al. (2018),[10] the authors investigated the prevalence of C-shaped root in human mandibular second premolars in Taiwan Chinese subpopulation using cone-beam computed tomography (CBCT). They observed a prevalence of 3.45% premolars with C-shaped root canal configuration. In the proposed study, we considered the same prevalence in the central Indian population. To obtain this estimate with 95% confidence level and with a margin of error (Ɛ) of 0.025, the required sample size calculated was **207**. The formula used for estimation was:

$$n = Z^2_{1-a}\, p(1-p)) / \varepsilon^2$$

Where,

Z1-α =1.96 (standard normal value for 5% level of significance)

p= 3.45% (Assumed prevalence of C-shaped root canal configuration in population) Ɛ= 0.05 (permissible error in estimation)

Substituting the values in the formula, a sample size of 207 was derived.

All eligible patients were provided with comprehensive information regarding the study's nature and the potential benefits. Informed consent was obtained from each participant. The study protocol underwent rigorous review and obtained approval from the Ethics Committee of Maharashtra University of Health Sciences, Nashik, Maharashtra, India. (Approval Number: IEC/VSPM DCRC/Dean Pg24/2020).

Sample size and selection: A total of 207 samples were calculated with a 95% confidence level and with a 0.025 margin of error. A study by Chen YC et al.,[10] investigated the prevalence of C-shaped root in human mandibular second premolars in Taiwan Chinese subpopulation using cone-beam computed tomography (CBCT). Study observed the prevalence of 3.45% premolars with C- shaped root canal configuration. The same prevalence was considered for calculating sample size for this study among Indian population. Power of the study was 80%, significance was 5% with a confidence interval of 95%, the following calculations were made.

Inclusion and exclusion criteria: CBCT from individuals above 14 years of age, with healthy mandibular premolars and complete root formation were included in the study. While, Mandibular premolars with caries involvement, endodontic treatment, root resorption, partially formed root apices and impactions were excluded.

Sirona Orthophos SL 3D CBCT machine with 3Diagnosys software (4.2 version) was used by all the centres included in the study.

Categorization of C-shaped Canals: Fan et al. (2004)[11] classification was practiced to categorize observed C-shaped canals. Experimental design and protocol: The study comprised 207 patients who met the predetermined inclusion and exclusion criteria, hailing from five different states of India (Maharashtra, Madhya Pradesh, Uttar Pradesh, Karnataka, Gujarat). Each patient underwent a cone-beam computed tomography (CBCT) scan, specifically targeting the first and second mandibular premolars on both sides. For analysis, axial section from the CBCT scan was chosen for each premolar, enabling assessment of the C-shaped canal configuration at three distinct levels: the coronal third, middle third, and apical third of the canal.

Parameters Assessed:

(a) Prevalence and position of C-shaped canals.

(b) Prevalence, position, depth of groove, and bilateral presence of radicular grooves.

(c) Bilateral presence of C-shaped canals

(a) C-Shaped canal (Figure 1):

Prevalence: The classification proposed by Fan et al. is followed to categorize.

Position: In the coronal section analysis, the position of C-shaped canal in was assessed. The measurements for the coronal section included: (Figure 2)

The distance from the cementoenamel junction (CEJ) to the initial appearance of the C-shaped canal system.

The entire length of the root, measured from the CEJ to the root apex.

(b) Radicular grooves:

Prevalence: Radicular grooves, which are developmental in nature and extend from the cementoenamel junction (CEJ) along the root surface to the apex, were identified in the CBCT slices.

Position: The position of the grooves was determined by measuring the distance from the CEJ to their first appearance along the root surface.

Depth: For assessing the depth of the radicular groove, an axial section was selected. A tangent line (AB) was drawn on the measured side of the groove, with the deepest point of the groove labelled as G and a corresponding point on the tangent labelled as N. The depth of the groove was then measured as the distance between points G and N. (Figure 3)

Additionally, the presence of bilateral C-shaped canals in mandibular premolars was identified using CBCT images. (Figure 4) Analysis: The analysis was performed using high-resolution micro-computed tomographic images and cone-beam computed tomography (CBCT) images of C1 configurations identified in the axial and coronal slices at the middle-apical level of the root (as depicted in Figure 2). Data analysis was carried out by two experts with more than 15 years' experience.

In instances where there was a discrepancy in observations between the two radiologists, a third experienced radiologist (25 years) analyzed the images to reach a consensus and obtain final measurements. This rigorous process ensured accuracy and reliability in the interpretation of the findings.

Statistical Analysis

The data regarding age and sex of the patients were recorded and transferred onto an Excel Spreadsheet 2010. The demographic details were summarized in terms of mean and standard deviation and sex was presented in terms of frequency and percentage. The presence of unilateral and bilateral occurrence of C-shaped mandibular canals and radicular grooves were analysed in terms of numbers and percentages to obtain prevalence. All statistical analysis were performed using IBM-SPSS Version-21 statistical software and the significance was tested at 5% level. The brief description of methods used is as below:

Measures of central tendency

The mean was measured to get an idea on where the center value is located in a data set. If $x1$, $x2$,...xn are the observations on a random variable X, then following measures of central tendency can be obtained:

- **Mean** for a set of observations is given by

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Measures of dispersion

The standard deviation is used to measure the spread of values in a sample. It gives an idea how far each data lies away from mean.

Standard deviation for a set of observations in given by 60

$$s = \sqrt{\frac{1}{(n-1)}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Where *x*i = observation on each object *n* = number of objects

Results

(Table 1) illustrates that 27.1% of first premolars exhibited the presence of a C-shaped canal, while 47.3% of patients showed this configuration in their first premolars. The highest prevalence of the C1 type was observed in first premolars, accounting for 25.8%. Among these, 11.1% of patients belonged to Maharashtra, followed by 9.7% in Madhya Pradesh.

The presence of C-shaped canals in second premolars was notably lower, with only about 2.7% of teeth exhibiting this configuration and 4.3% of patients being affected.

The mean distance from the cementoenamel junction (CEJ) to the first appearance of the C-shaped canal was 3.7 ± 1.7 mm for the first premolar. For the second premolar, the mean distance was slightly shorter at 2.9 ± 2.1 mm. The mean root length from the CEJ to the apex was 14.2 ± 1.5 mm for the first premolar and 15.8 ± 2.3 mm for the second premolar.

(Table 2) indicates that the bilateral presence of C-shaped canals was observed in approximately 6.8% of cases for the first premolar and about 0.5% of cases for the second premolar.

(Table 3) highlights regional variation in the prevalence of C-shaped canals, with Maharashtra showing the highest prevalence and Gujarat the lowest. For second premolars, the highest distribution of C-shaped canals was observed in Madhya Pradesh, while none were seen in Uttar Pradesh and Gujarat.

The radicular groove was found in only 0.72% of first premolars, while none of the second premolars exhibited such grooves.

Discussion

Fan et al. (2004) [7] proposed a comprehensive classification system for C-shaped canals for mandibular premolars, which categorizes these canals into five main types based on their morphology and configuration: Type C1: Continuous C-shaped canal without any division. Type C2: Canal separates into two distinct parts before merging again. Type C3: C-shaped canal with a distinct fin or septum dividing the canal into two or more separate canals. Type C4: Oval canal. Type C5: No canal. The study revealed a significant prevalence of C-shaped canal configurations in mandibular premolars, particularly in first premolars. The prevalence observed in this study is similar with research by Gu Y et al. (2013)[11], Boschetti E et al. (2017)[12] and Zhang Y et al.[13] confirming that approximately one-quarter of first premolars exhibit this complex canal anatomy.

The highest prevalence of the C1 type among first premolars, particularly in Maharashtra (11.1%), suggests notable regional variation. This finding is consistent with Kottoor J et al. (2013) [14], who reported a correlation between root canal morphology and ethnicity. However, this findings is in contrast with Wu YC et al. (2018)[15], who found a dominance of the C3 type and in a different population highlighting the variability in C-shaped canal types across different ethnic groups.

The significantly lower prevalence of C-shaped canals in second premolars (2.7%) aligns with the findings of Mashyakhy MH et al. (2020) [16], Yu X et al. (2012) [17] and Rae O et al. [18] suggesting that this canal configuration is less common in these teeth. In contrast study by Brea G [19] and Srivastava S et al. [20] reported higher prevalence of C-shaped canals in second premolar that could be attributed to differences in sample populations and methodologies.

The prevalence of C1 type canals was highest among mandibular first premolars in this study. The classification system employed here plays a pivotal role in comprehending the intricate variations and complexities of root canal anatomy, which are essential for achieving successful endodontic treatments. The mean distances from the CEJ to the first appearance of the C-shaped canal and the mean root lengths were similar to those reported by Fan et al. (2012) [21], reinforcing the similarities of these anatomical features across different studies and among various population.

The bilateral presence of C-shaped canals was found in 6.8% of first premolars, which is higher than the 3.5% reported by Piorno RC et al. (2021)[22] whereas no bilateral presence was noted in second premolars, similar to Mashyakhy MH et al. (2020)[16]. This suggests a possible genetic or anatomical predisposition for bilateral occurrence in first premolars.

Regional variation in the prevalence of C-shaped canals has been previously reported, Zhang Y et al. [13] and Kottoor J et al. [14] found a correlation between root canal morphology and ethnicity. In the present study, a high prevalence of C-shaped canal configuration was observed in first premolars in Maharashtra, suggesting that the population residing in this state has a pronounced tendency for this anatomical variation.

Conversely, Gujarat had the lowest percentage of C-shaped canals.

For second premolars, the highest distribution of C-shaped canals was observed in Madhya Pradesh, while none were seen in Uttar Pradesh and Gujarat. This highlights the regional variation in the prevalence of C-shaped canals within different states.

The present study also evaluated the presence of radicular grooves alongside C-shaped canals. The radicular groove is a distinctive anatomical feature of mandibular premolars. In the present study, only 0.72% of first premolars were found to have radicular grooves, while none of the second premolars exhibited such grooves. This finding contrasts with variable presence rates reported in the literature, such as 21.42% by Boschetti et al. in 2017[12], 16.6% by Wu YC et al. in 2018[15] and 14.68% by Büyükbayram IK et al. in 2019[23] Moreover, the depth of radicular grooves observed in different studies varies, ranging from shallow to moderate to deep. Gu Y et al. in 2013[11] found that the depth of grooves ranged from 0.18 mm to 1.24 mm, categorized as shallow, moderate, and deep, respectively. This demonstrates variability in the depth of radicular grooves observed across different studies.

The wide range of occurrence of C-shaped canals and radicular grooves observed across different studies can be attributed to multiple factors, including genetic or ethnic predilection, variations in the methods used for evaluation (in-vivo, in-vitro, CBCT, spiral CT, micro-CT) and differences in sample size.

The limitations of the present study include variation in voxel size, which is a common issue in multicentric research. Future studies with larger sample sizes and long-term follow-up focusing on racial variation and genetic prevalence are needed to provide a clearer understanding of the prevalence and morphology of C-shaped canals and radicular grooves in mandibular premolars.

Conclusions

This study investigated the prevalence of C-shaped canals and radicular grooves in mandibular premolars using cone-beam computed tomography (CBCT) scans. The findings revealed a notably higher prevalence of C-shaped canals in mandibular first premolars compared to second premolars. Specifically, C-shaped canals were observed in 12.5% of mandibular first premolars, while none were identified in mandibular second premolars. Radicular grooves were found to be rare, with only 0.72% of mandibular first premolars exhibiting them, and none in mandibular second premolars. No cases of bilateral radicular grooves were noted. These results underscore the importance of CBCT in accurately assessing root canal morphology, particularly in identifying the presence of C-shaped canals. Such insights are crucial for enhancing the precision of root canal treatments and improving clinical outcomes in dental practice. Future studies can further build upon these findings to refine treatment protocols and expand our understanding of anatomical variations in dental morphology.

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- Subharti Dental College, Meerut, Uttar Pradesh, India

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Legend Tables & Figures

Table 1: Presence of C-shaped canal system in 1st premolar and 2nd mandibular premolar with respect to patient and the teeth involved:

Teeth	Patients with C-shaped Canal System (Frequency)	Patients with C-shaped Canal System (Percentage %)	Teeth with C-shaped Canal System (Frequency)	Teeth with C-shaped Canal System (Percentage %)
1st Premolar	98	47.3	112	27.1
2nd Premolar	9	4.3	11	2.7

Table 2: Bilateral presence of C-shaped canal system with respect to 1st premolar and 2nd mandibular premolar

Teeth	Frequency	Percentage (%)
1st Premolar	14	6.8
2nd Premolar	2	0.5

Table 3: Mean location of C-shaped canal with respect to 1st and 2nd mandibular premolar

Teeth	Distance from CEJ to the First Presence of C-shaped Canal (Mean)	Standard Deviation	Entire Root Length (CEJ to Apex) (Mean)	Standard Deviation
1st Premolar	3.7	1.7	14.2	1.5
2nd Premolar	2.9	2.1	15.8	2.3

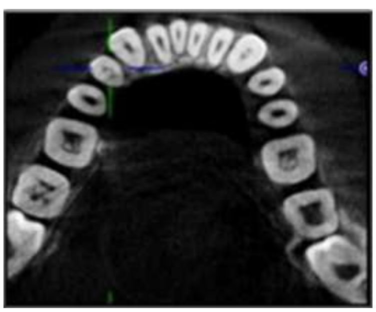

Figure 1: C-shaped canal

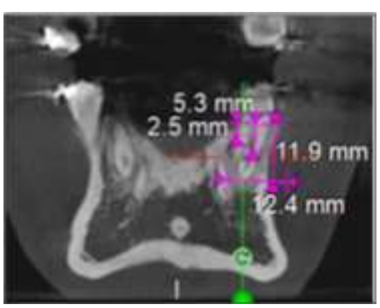

Figure 2: Position of C-shaped canal

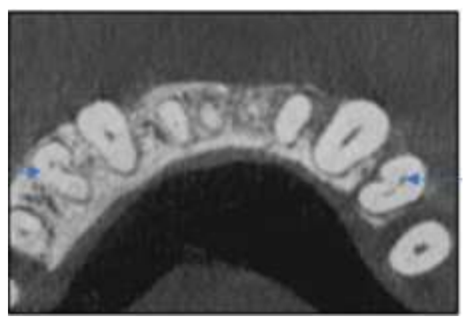

Figure 3: Radicular groove measurement

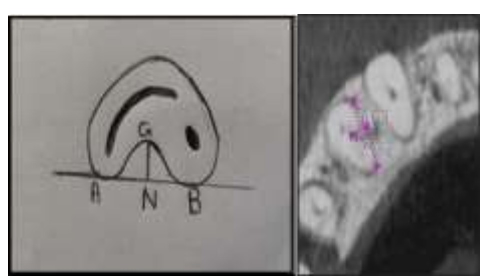

Figure 4: Bilateral presence of C-shaped canal