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A COMPREHENSIVE CONE BEAM COMPUTED TOMOGRAPHY IMAGING ANALYSIS OF CONTRALATERAL MANDIBULAR FIRST PREMOLARS ROOT CANAL ANATOMY

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ABSTRACT

Objective: This research explored the root canal patterns and configuration in the contralateral lower 1st bicuspid by conducting a detailed analysis of cone-beam computed tomography (CBCT) images. **Materials and Methods:** The sample includes analysis of 508 contralateral mandibular 1st premolars CBCT images from adult patients. The P-value was set at the significance level equal to or less than 0.05, and the Chi-square test was employed to examine proportion variations. **Results**: 6.3% of the inspected mandibular 1st premolars were found to have two roots. Vertucci's classifications identified were Category I at a high rate of 89.8%, Category II at a much lesser rate of 2.1%, and Category V at 8.1%. Furthermore, the general occurrence of the C-shaped canal in the lower 1st bicuspid was 8.6%. **Conclusions:** The current comprehensive analysis of the contralateral mandibular 1st premolars concluded that there is no significant difference between the root canal patterns and configurations of the contralateral mandibular first premolars.

KEYWORDS: C-shaped canal, root canal configurations, mandibular premolar anatomy.

INTRODUCTION

The primary goal of root canal therapy is to exterminate the necrotic pulp and bacterial biofilm from the root canals. Root canal therapy fails when canals are not located properly, allowing bacterial infection to persist inside the untreated canal. The root canal system displays a broad range of anatomical differences. These variations can notably escalate the complexity of endodontic procedures. Proper biomechanical cleaning and shaping, followed by a well-sealing obturation of all root canals, necessitates an extensive understanding of the root canal's anatomy and structure to accomplish successful outcomes [(1)]. Dental morphology can vary among populations with distinct geographic origins and ethnic backgrounds. Many studies have been conducted on the morphology of root canals, specifically examining variations in different teeth across various regions and populations, as well as documenting unique cases of root canal morphology [(2,3)]. These studies have identified differences in root canal morphology based on tooth position, race, and gender [(2,4)]. Developmental grooves on mesial and distal surfaces result in an oval-shaped root. The intricacy of root canal anatomy is closely linked to the existence and degree of root grooves.

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Although the lower 1st bicuspid is a single-rooted tooth, in most cases, the structure of their canals could involve anything from a solitary canal to multiple canal pathways, possibly two or more [5]. Studies have found that three or more canals in the lower premolars is unusual, with an incidence estimated to be between zero and five percent. The C-shaped canal is a complex root canal anatomy that might be encountered in the mandibular first premolars[6].

Cone Beam Computed Tomography (CBCT) offers three-dimensional images of teeth and also surrounding structures, including better detection of the peri-radicular lesion and identification of the complex root canal anatomy [7]. This is particularly useful in evaluating radiographic modifications linked to potential health conditions or the existence of diverse morphological alterations [8].

The mandibular 1st bicuspid root canal system can pose significant challenges in cleaning and shaping. Tabassum suggested that the complexity of the canal structure could contribute to a higher rate of failure in endodontic treatments of this tooth [9]. Slowey [10] noted that mandibular premolars are the most complex teeth in endodontic therapies because of the extensive variability in their root canal structures. For successful endodontic outcomes, it is essential to thoroughly clean, disinfect, and fill the entire root canal system. The prevalence of one canal system ranges from 69.3 to 86%, two canals from 14 to 25.5%, and three canals from 0.4 to 0.9%, whereas lower second bicuspids had a single canal in 97.5% and two canals in 2.5%[11-14]. Vertucci outlined five distinct canal patterns for the mandibular first premolar[14]. The root canals in mandibular 1st bicuspids typically appear cone-shaped but tend to change to a ribbon shape in the coronal one-third of the root [15]. Furthermore, an extensive buccolingual canal could abruptly narrow into a bifurcation, forming two tiny canals [15].

When observed from the axial perspective, the root canal orifice has a C-like appearance, hence termed "C-shaped." This shape is due to the fin or web that joins the discrete root canals [16]. The opening of each canal is situated beneath the cement-enamel junction (CEJ). It is a singular, ribbon-like shape, forming an arc (either buccal or lingual) that links all primary channels to the distal channel[16]. Managing the C-shaped canal poses challenges in cleaning and filling, particularly because it remains uncertain whether the C-shaped opening identified on the pulp chamber floor extends to the apical third of the root. A C-shaped canal is formed due to incomplete fusion of the Hertwig epithelial root sheath and developed through the merging process over time due to the gradual deposition of cementum[17].

C-shaped canals can be categorized into five types: C1: continuous "C" with no distinct separations; C2: A semicolon-shaped canal; C3: Two (a) or three (b) distinct canals with both; C4: A single canal observed in appearing in axial view, and C5: No visible canal lumen, usually seen in apical 1/3rd of the tooth. In lower premolars, the C1 or C2 configuration usually begins around the mid-root level, with the canal opening and the root canal starting in the coronal 1/3rd of the tooth[18].

This study aimed to investigate the configuration of the root canal system and the root structure in the contralateral 1st mandibular premolar. The research identified the count of roots and root canals, their arrangement, and various distinctive anatomical features.

MATERIALS AND METHODS

Random screening of 268 participants included 128 males and 140 females above 18 years old with both side mandibular 1st premolars CBCT images (Sirona XG CBCT 8x8 FOV with PC,Germany) and participants who gave informed consent to use

their data for research purposes anonymously were included in this study. CBCT image was excluded if the image was unclear, if the mandibular premolar was endodontically treated, if the image was taken for expected abnormal root canal anatomy, or if the patient's age is less than 18 years. The research approval was gained through the Faculty of Dentistry Research Committee (reference number: 45123724).

The average age, along with the standard deviation, was calculated to be 39.3 ± 13.4 years with the minimum age of 18 years and maxmum age of 70 years. The radiographic images were taken for various diagnostic reasons, excluding those for expected abnormal root canal anatomy.

Initially, the number of roots and canals were recorded for each tooth examined, followed by shape, as classified by Bueno et al [19]. C-shaped root canal systems were recorded according to the Fans classification [20]. Additionally, the longitudinal groove location of the root (buccal, lingual, mesial, distal) was assessed. Root canals were also classified according to Vertucci's classification [14] .

The raw data from the patient's images were analyzed using Statistical Package for the Social Sciences (SPSS) version 23.0. The frequency and percentage of various root canal configurations and their correlations with right and left mandibular first premolar were measured, and the differences between the groups were analyzed using the Chi-squared test with P<0.05 as significance.

RESULT

The overall frequency of one root in the mandibular 1st premolar was 94.1% compared to 5.9% of two roots. Although the frequency of two roots was higher in the right 1st mandibular premolar (7.8%) compared to the left (4.2%), the difference was not statistically significant (Table 1).

TABLE (1) Number of Roots, Vertucci Canals Category, and C-Shaped Root of the Mandibular first Premolars

	Number of Roots	Vertucci's classification	C shape
Mandibular 1st right premolar			
	1.00 236(92.2%)	I 208 (89.8%)	Yes 24(9.4)
	2.00 20 (7.8%)	III 5 (2.1%)	No 232(90.6%)
		V 19 (8.1%)	
Total	256	232	256
Mandibular 1st left premolar			
	1.00 240(95.2%)	I 208 (89.8%)	Yes 20(7.9)
	2.00 12 (4.2%)	III 5 (2.1%)	No 232(92.1%)
		V 19 (8.1%)	
Total	252	232	252
P value	0.125	0.167	0.102

Three categories of Vertucci's root canal classification were identified in this study. Class I (89.7%) was the most prevalent category, followed by class V in (8.1%) of the cases. Class III was identified in (2.2%) of the cases.

A c-shaped canal in the lower 1st bicuspid was reported in 8.6% of the cases. C-shaped canal in the right lower 1st premolar was more frequently reported than in the mandibular left 1st premolar (9.4% vs. 7.9); however, the difference was not statistically significant (Table 1). The study analyzed the C-shaped canal configurations of mandibular 1st premolars at three different levels: coronal, middle, and apical, using Fan's classification. The study observed that all canal configurations of the C-shaped root were evident in the mandibular 1st premolar, as shown in Table 2.

TABLE (2) Mandibular First Premolars C-Shaped canal Category and root groove location

Coronal 3rd	P value	Middle 3rd	P value	Apical 3rd	P value	Groove location	P value
Mandibular 1st right premolar							
C1 1 (4.2%)		C1 8 (33.3%)		C3A 16 (66.6%)		Lingual 4 (16.6%)	
C4 23 (95.8%)	0.011	C2 8 (33.3%)	0.203	C3B 4 (16.6%)	0.040	Mesial 20 (83.4%)	0.021
		C3A 8 (33.3%)		C4 4 (16.6%)			
Mandibular 1st left premolar							
C1 1(5%)		C1 8(40%)		C3A 12 (65%)		Lingual 4(20%)	
C4 19(95%)	0.026	C2 4(20%)	0.105	C3B 4 (20%)	0.043	Mesial 16(80%)	0.036
		C3A 4(20%)		C4 3 (15%)			
		C4 4(20%)					

Yet, the occurrence of C4 canal configuration, as per the statistical analysis, was significantly greater in the coronal third level, while C3a is the more frequently encountered canal configuration at the apical third level. The longitudinal groove was frequently visible on the mesial side (81.8%) as seen in Figure 1.

The canal configurations recorded in this study, as labeled in Table 3, include oval, circular, conical, ribbon, figure of eight, and drop shape.

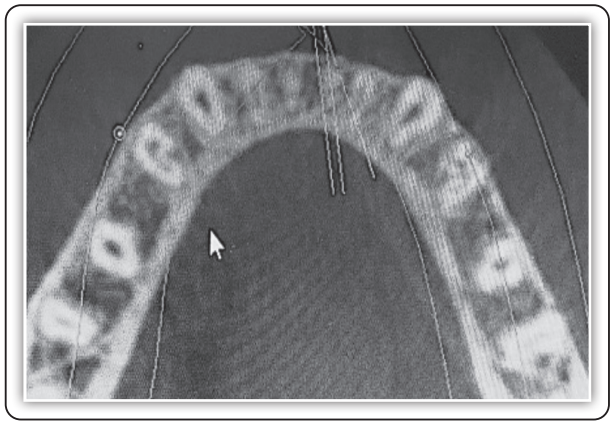

FIG (1) CBCT image showing right and left mandibular first premolar with c-shape root, different number of canals, and mesiolingual groove which is the most frequent location

TABLE (3) Root canals configuration at three cross sectional levels

	Coronal third	Middle third	Apical third
Mandibular 1st right premolar			
	Circular 20 (8.6%)	Circular 120 (51.7%)	Circular 216 (93.1%)
	Conical 4 (1.7%)	Conical 4 (1.7%)	Oval 8 (3.4%)
	Oval 196 (84.4%)	Oval 84 (36.2%)	Ribbon. 4 (1.7%)
	Ribbon 12 (5.2%)	Ribbon 20 (20%)	Figure of Eight 4 (1.7%)
		Drop shape 4 (1.7%)	
Total	232	232	232
Mandibular 1st left premolar			
	Circular 16 (6.9%)	Circular 123 (53%)	Circular 229 (98.7%)
	Conical 4(1.7%)	Conical 4 (1.7%)	Oval 8 (3.4%)
	Oval 208 (89.6%)	Oval 81 (34.9%)	Ribbon 4 (1.7%)
	Figure of Eight 4(1.7%)	Ribbon 16 (6.9%)	
		Drop shape 8(3.4%)	
Total	232	232	232

The oval-shaped canal configuration is the most frequent at the coronal level of the mandibular 1st premolars investigated in this study, with a prevalence of 87.06%. At the apical level, the circular canal configuration is the most frequently reported, with a prevalence of 95.9%. Table 4 shows the incidence of c-shaped root.

TABLE (4) Mandibular first premolar with C-Shaped Root in different population surveys

Study	Technique	Patient sample	Prevalence of C shape root
(21)	CBCT	Venezuela (380)	28.94%
(22)	CBCT	Saudi (397)	1.5%
(23)	Micro-CT	China (205)	12.36%
(24)	CBCT	Thai (349)	3.72%
(25)	CBCT	Saudi (242)	17.4%

DISCUSSION

Numerous studies have explored the morphology of root canals, focusing on variations in different teeth across diverse regions and populations. This retrospective study delved into the root canal configuration of the contralateral 1stlower bicuspid, analyzing CBCT images obtained from 268 patients, comprising 128 males and 140 females aged between 18 and 70 years.

In this study, the predominant phenomenon of a single root in the mandibular 1st bicuspid was 94.1%, while the presence of two roots constituted 5.9%. Notably, the prevalence of two roots was higher in the right 1st mandibular premolar (7.8%) in contrast to the left (4.2%).

In this investigation, the overall occurrence of a C-shaped canal in the mandibular 1st premolar was 8.6%, differing notably from the findings in studies conducted by Brea et al (21). (28.94%) and Mashyakhy et al (22). (1.5%). Yet, it is within the globally reported incidence of c-shaped root. Various population surveys reported 12.36% and 3.72% prevalence by Dou et al (23) and Arayasantiparb and Banomyong (24). In cases where mandibular premolars display C-shaped root canal system configurations, it is advisable to employ magnification and instrumentation with an anti-curvature technique. This recommendation stems from concavities in the roots, thin dentinal walls in the lingual zone near the mesial area, and the narrow nature of the canals.

In Portugal, the prevalence of C-shaped roots was 2.3%, lower than the study by Srivastava et al.(25) where the prevalence was 17.4%. Differences in the identification methods of C-shaped roots among studies and the ethnic diversity of the samples may account for these variations. Such insights are valuable for clinicians, assisting in preventing perforations and root fractures.

The current research results affirm that most 1st teeth exhibit a single root (94.1%). These findings align with previous studies conducted in populations with diverse ethnicities. Notably, the Asian group demonstrated a higher prevalence of single-roots in upper 1st premolars (83.2%) and lower second molars (45.4%) compared to whites, where the prevalence was 48.7% and 14.3%, respectively.

Additionally, three-rooted configurations in mandibular 1st molars were more prevalent in Asians (25.9%) compared to whites (2.6%) (2,3). Furthermore, our study identified that Vertucci canal patterns of type I, III, and V were most prevalent, with frequencies of 89.1%, 8.1%, and 2.2%, respectively. In the Asian ethnic group, there was a higher prevalence of Vertucci type I configuration, whereas the white group demonstrated a greater variety of multiple root canal system morphologies.

Our data on root canal configurations are consistent with prior studies in Gujarati and Chinese populations, indicating that Type I is the most prevailing canal pattern in lower 1st premolars, followed by types III and V(23,26). This study generally

supports previous observations regarding root and canal morphology in mandibular 1st premolars among diverse ethnic populations.

In this study, the root canal's shape at the coronal level was predominantly identified as C4 in most cases. This observation underscores a crucial clinical consideration, as most C-shaped roots do not exhibit the typical appearance of these orifices in lower 2nd molars. Furthermore, this study primarily observed an oval-shaped canal configuration at the coronal third level of the lower 1st premolar. This highlights the necessity for developing new methods to identify C-shaped roots, particularly in lower bicuspids, as the clinical appearance of the orifice may not be adequate for accurately identifying the C-shaped root.

This observation aligns with Ingle's characterization of the canal shape in mandibular premolars, which describes an oval shape at the coronal level, transitioning to an elliptical shape at the mid-root level, and finally becoming circular in the apical one-third [9].

In contrast to prior findings, the current study identified the C4 canal configuration as the most prevalent in C-shaped roots at the coronal level, deviating from the reported prevalence of the C1 configuration by Mashyakhy et al [22]. This discrepancy suggests a difference in the dominant canal pattern at the coronal third, with our data indicating the C4 canal pattern is more frequent in C-shaped mandibular molars within this population. Further research is warranted to elucidate the predominant canal configurations in different root segments of C-shaped molars across diverse populations.

In our current study, the longitudinal groove was predominantly situated on the mesial root surface in C-shaped mandibular premolars, with a frequency of 81.8%, consistent with earlier research [5,21,25] .

Our findings substantiate the importance of identifying the position of the longitudinal groove, often located mesially, as it is crucial for preventing procedural errors such as strip perforations during root canal treatment in these teeth [27]. Additionally, as demonstrated by Fan, [18] it's noteworthy that some isthmuses connecting major canals may be found near the external groove in C-shaped roots. However, this occurrence is limited in number.

Hence, clinicians should remain vigilant, recognizing the canal isthmuses, which can also be close to the groove in certain cases. This study underscores the significance of accurately locating the longitudinal groove, frequently found on the mesial aspect, to prevent complications and procedural mishaps during endodontic therapy on C-shaped mandibular premolars.

While this investigation provides crucial insights into the effectiveness of various imaging modalities for identifying root canal patterns and configurations in mandibular premolars, it is essential to acknowledge certain limitations. The study's sample size stands out as one such constraint, emphasizing the necessity for larger-scale prospective studies to bolster the robustness of the findings. The study advocates for a multidisciplinary approach to their management recognizing the intricacies of the results. Dentists, in particular, are encouraged to maintain a vigilant approach, keenly observing changes that may not directly relate to the primary reasons for the initial examination. Moreover, the study underscores the importance of categorizing root canal configurations and emphasizing their clinical assessment as an integral aspect of proactive patient care.

While this study has made valuable contributions, it is essential to delineate its limitations. The cross-sectional design, although informative, imposes constraints on establishing causal relationships. Future research efforts could significantly benefit from adopting longitudinal study designs to unravel temporal dynamics in the context of root canal patterns and configurations. Additionally, the study underscores the importance of

standardizing CBCT protocols to ensure consistency across studies and enhance comparability. Investigating additional factors contributing to gender-based differences in prevalence is a crucial pathway for future research endeavors. This exploration aims to enhance diagnostic accuracy and expand our understanding of the intricate canal patterns observed.

CONCLUSIONS

This extensive CBCT analysis of mandibular 1st premolars found no significant differences in root canal configurations between contralateral premolars. Most premolars had a single root and multiple canals and were frequently seen within those single roots. CBCT was beneficial for identifying complex anatomical variations that may be challenging to discern on intraoral radiographs alone. Furthermore, the prevalence of C-shaped roots showed asymmetry between contralateral premolars, though not statistically significant. Overall, this study highlights the complex morphologies of mandibular 1st premolars, with CBCT improving the detection of multiple canals and C-shaped variants. Bilateral premolars generally exhibited symmetrical root and canal anatomies. Further research on larger populations is warranted to understand the complete range of anatomical diversity in these teeth.

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