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Original Article

Prevalence and morphology of multiple roots, root canals and C-shaped canals in mandibular premolars from cone-beam computed tomography images in a Thai population

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Abstract *Background/purpose:* Variations in root and root canal morphology of mandibular premolars of Thais has not been reported, and understanding these variations enhances endodontic success. The purpose was to investigate prevalence and morphology of multiple roots, root canals and C-shaped canals in mandibular premolars in a Thai population from cone-bean computed tomography (CBCT) images.
Materials and methods: A total of 349 first mandibular premolars and 416 second premolars from CBCT images with 0.125-mm voxel size and 60 × 60 mm field of view were evaluated. Number of roots, root canals, and C-shaped canals were recorded and statistically analyzed using chi-square test. Root canal configurations were defined according to the Vertucci's classification. Levels and distances of separated multiple canals were reported.
Results: Multiple roots in mandibular first premolars were found at 5.73% while none of second premolars had. Multiple root canals were found in the first premolars at 19.48% and the second premolars at 3.85%. C-shaped canals (C1/C2) were found in the first premolars at 3.72% and the second premolars at 0.48%. All parameters in the first premolars were significantly higher than in the second premolars ($p < 0.01$). The majority of multiple root canals were defined as Vertucci's type V (1–2 canals). Multiple root canals were frequently separated at the middle level of roots about 6.5–7.0 mm from the cementoenamel junction.

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Conclusion: Prevalence of multiple roots/root canals and C-shaped canals in mandibular first premolars were significantly higher than in mandibular second premolars. Level of separation in multiple root canals was frequently at the mid-root level.

Introduction

The main objective of root canal treatment in teeth with pupal necrosis and periapical lesion is to remove necrotic pulp and eradicate bacterial biofilm from root canal systems.[1] Unable to locate and treat all canals is one among the causes of failure in root canal treatment, which bacterial infection remains inside the missed canal.[2] All dental practitioners must require knowledge of root canal morphology and keep respect to the anatomy to achieve success in root canal treatment.[3]

Root canal morphology is usually categorized into types I to VIII and supplemental categories according to Vertucci's classification.[4] Mandibular premolars commonly have a single root and root canal.[5,6] However, multiple roots and root canals variation in root canal morphology of mandibular premolars has been comprehensively reviewed.[5,6] Cleghorn et al. reported that the variation in the first mandibular premolars is markedly higher than the second mandibular premolars.[5,6] In addition, this variation is frequently found in Asian and African at a higher prevalence than Caucasian.[5,6] Endodontic treatment in these mandibular premolars with the variations must be performed with caution.

C-shaped canals are frequently detected in mandibular second molars.[7] However, this variation is also possibly found in mandibular premolars.[7,8] In cross-section, root canal morphology of C-shaped canals in mandibular premolars is categorized into C1 to C6 canal configurations[8] that are similar to those configurations of second molars.[9] To justify the C-shaped configuration, C1 (continuous 'C' peninsula) or C2 (discontinuous 'C' semi-peninsula) must be present at least a level of root canal, and with a longitudinal groove on the external root surface.[8,10,11]

However, there are differences between the C-shaped canals in mandibular premolars and second molars. Firstly, C1 or C2 configuration in mandibular premolars generally begins at the mid-root level, and the canal orifice as well as root canal at coronal one-third is just a wide round-shaped canal.[8,12] In contrast, the C-shaped configuration in second molars is generally starting from the pulpal floor.[9] Secondly, the radicular grooves are frequently detected at the mesial or distal site of the mandibular premolars with C-shaped canals,[8,10,13] while the buccal or lingual groove is more likely to detect in the second molars.[11]

Several laboratory methods are available for studying root canal morphology such as clearing tooth technique, tooth sectioning, and micro computed tomography (micro-CT),[14] but these methods cannot be clinically used. Cone-beam computed tomography (CBCT) is an extra-oral radiographic technique used for oral-maxillofacial examination that presents the images in three-dimensional (3D) views-i.e. axial, sagittal, and coronal planes.[15] This 3D radiographic technique is appropriate and clinical relevant for studying root canal anatomy.[16,17]

The variation of root and root canal morphology in mandibular premolars of Thais has not yet been reported. This prevalence especially in the first premolars may be as high as those reported from CBCT or micro-CT in other nationalities- such as Chinese,[10,13,17–19] Korean,[20] Brazilian,[21] Chilean,[22] Belgian,[22] German,[23] Spanish,[24] and American.[25] In contrast, less variation has been reported in Turkish,[26,27] and Saudi.[28] Therefore, this study aims to investigate the prevalence and morphology of multiple roots and root canals in mandibular first and second premolars in a Thai population from CBCT images.

Materials and methods

The study protocol was approved by the institutional ethic review committee (MU-DT/PY-IRB 2016/DT074). Number of root and root canal morphology of mandibular first and second premolars were studied from CBCT images of Thai patients in the Oral and Maxillofacial Radiology Department during a period of 2013—2016. These CBCT images were taken using 3D Accuitomo XYZ Slice View Tomograph (*J. Morita, Kyoto, Japan*) under full-rotation mode with a setting parameter of 90 kV, 5.0 mA, 17.5 s exposure time, 0.125- mm voxel size and 60 × 60 mm field of view. Each patient's identification was blinded with a numeric code by a concern about privacy. CBCT images were included following the inclusion and exclusion criteria.

The inclusion criteria of the recruited teeth in CBCT images were 1) mandibular first or second premolars; and 2) complete root formation. The exclusion criteria of the recruited teeth were 1) with root canal filling or post; 2) with crowns or large amalgam restorations that a cause of the scattering effect; 3) root canal was obliterated and could not be identified; 4) with external or internal root resorption; and 5) with vertical or horizontal root fracture.

CBCT images were evaluated to find out multiple roots, root canals, or C-shaped canals in OneVolume Viewer software version 1.5.0 (*J. Morita*). To begin with, the axis of mandibular premolar was adjusted vertically. Next, the number of roots and root canals were analyzed from the cross-sectional images along the axial plane. The images in the sagittal and coronal planes were also observed to identify the possibility of multiple roots, root canals, and C-shaped canals. Measuring of root length and level of root canal separation (if any for multiple canals) was performed in the software.

From CBCT analysis, the data were collected and recorded, as follows: 1) mandibular first or second premolar; 2) number of roots; 3) number of root canals and root canal morphology; 4) C-shaped canal (if any) and its canal configuration. The morphology of root canal was classified based on the Vertucci's classification.[4] In the teeth with multiple root canals, the other two collected parameters were 1) level of root canal separation-apical, middle, or coronal one-third of root length; and 2) distance (mm) from the cementoenamel junction to each level of canal separation, which was calculated into mean ± standard deviation.

Statistical analysis

For statistical analysis, the prevalence of multiples roots, root canals, and C-shaped canals in mandibular first and second premolars were calculated into percentage. The prevalence of these variations were compared between the first and second premolars using the chi-square test with a significant level set at 0.05. In addition, the prevalence in the variations of premolars were also compared between the genders, and the left/right sides.

Results

In this study, the CBCT images of 765 teeth from 439 patients (142 males and 292 females) were included. A total of 349 mandibular first premolars and 416 mandibular second premolars were analyzed (Tables 1 and 2).

For the mandibular first premolars, 329 teeth (94.27%) had one root, 17 teeth (4.87%) had two roots, and three teeth (0.86%) had three roots (Table 1). With the multiple roots, 9 teeth and 11 teeth were detected in the left premolars and the right premolars. According to the Vertucci's classification, the mandibular first premolars were classified into six configurations: type I (281 teeth, 80.52%), type II (two teeth, 0.57%), type III (one tooth, 0.29%), type V (59 teeth, 16.90%), and type VII (one tooth, 0.29%) (Table 1). With the multiple root canals, 35 teeth and 33 teeth were detected in the left premolars and the right premolars.

In addition, the root canals of mandibular first premolars (n = 5, 1.43%) had variations that were not able to be classified following the Vertucci's classification. These teeth had the variations in root canal configurations as follows: a) 1—3 canal configuration (n = 4) (Fig. 1), a single canal at the coronal level of root was divided into three canals at the middle level; b) 1-3-1 canal configuration (n = 1), a single canal at the coronal level was divided into

Table 2 The distances (mm) from the cementoenamel junction (CEJ) to each level of canal separation and the levels of root canal separation in the 68 and 16 mandibular first and second premolars with multiple root canals.

	Mandibular first premolar (n = 68)	Mandibular second premolar (n = 16)
Level of root canal separation		
Coronal	13 (19.12%)	2 (12.50%)
Middle	52 (76.47%)	13 (81.25%)
Apical	3 (4.41%)	1 (6.25%)
Distance from CEJ to the level of root canal separation (mm)		
Coronal	4.17 ± 0.69	4.29 ± 0.95
Middle	6.46 ± 1.68	6.92 ± 1.81
Apical	9.85 ± 1.53	13.03

Table 1 Number of roots, root canal morphology, and C-shaped canals in the mandibular first and second premolars.

	Mandibular first premolar (n = 349)	Mandibular second premolar (n = 416)
Number of roots		
1 root	329 (94.27%)	416 (100%)
2 roots	17 (4.87%)	0
3 roots	3 (0.86%)	0
Root canal morphology		
Vertucci's classification (root canals)		
Type I (1-1)	281 (80.52%)	400 (96.15%)
Type II (2-1)	2 (0.57%)	0
Type III (1-2-1)	1 (0.29%)	4 (0.96%)
Type V (1-2)	59 (16.90%)	12 (2.89%)
Type VII (1-2-1-2)	1 (0.29%)	0
Unclassified	5 (1.43%)	0
C-shaped canal	13 (3.72%)	2 (0.48%)
Canal configuration		
C1, continuous 'C' peninsula	7 (53.84%)	1 (50.00%)
C2, discontinuous 'C' semi-peninsula	6 (46.16%)	1 (50.00%)
Site of radicular groove		
M groove	5 (38.46%)	2 (100%)
Li groove	8 (62.54%)	0

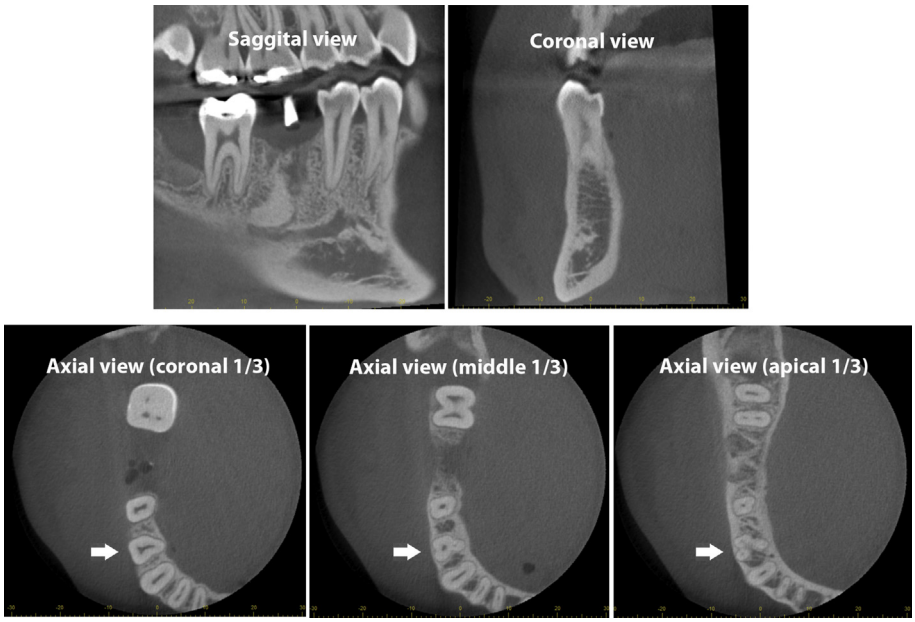

Figure 1 CBCT images of the mandibular right first premolar with three separated roots beginning at the middle level of root. One large oval-shaped root canal was observed at the coronal one third before separated into the three root canals-lingual, mesio-buccal and mesio-lingual, in the three divided roots.

three canals at the middle level that were confluent at the apical level.

For the mandibular second premolars, all 416 teeth (100%) had one root (Table 1). The mandibular second premolars were able to be categorized into only three configurations: type I (400 teeth, 96.15%), type III (four teeth, 0.96%), and type V (12 teeth, 2.89%) (Table 1). With the multiple root canals, nine teeth and seven teeth were detected in the left premolars and the right premolars.

C-shaped root canals were found in 13 mandibular first premolars (3.72%; seven teeth on the left and six teeth on the right) and two mandibular second (right) premolars (0.48%) (Table 1). In the first premolars, C-shaped root canals were presented with the configuration C1- seven teeth (53.84%) (Fig. 2), and C2- six teeth (46.16%) at least in

Figure 2 CBCT images of the mandibular left first premolar with the C-shaped root canals. This tooth had an oval-shaped root canal at the coronal one-third before the root canal was changed into C-shaped morphology (C1 configuration-continuous 'C' peninsula) with the lingual radicular groove on the root surface.

a cross-section of root canals. In the two second mandibular premolar, C-shaped root canals were presented with C1 (50%), and C2 (50%) configurations. The radicular grooves on the root surfaces were found mesially in five teeth (38.46%) and lingually in eight teeth (62.54%) (Fig. 2). The grooves were only located mesially (100%) in the two mandibular second premolars with C-shaped root canals.

The 68 mandibular first premolars with multiple root canals had a chance (%) of the distances from the CEJ (mm) of root canal separation at coronal 1/3— 19.12% (4.17 ± 0.69 mm); at middle 1/3— 76.47% (6.46 ± 1.68 mm); and at apical 1/3— 4.41% (9.85 ± 1.53 mm) (Table 2). The 16 mandibular second premolars with multiple root canals had a chance of the distances of root canal separation at coronal 1/3— 13.33% (4.29 ± 0.95 mm); at middle 1/3— 80% (6.92 ± 1.81 mm); and at apical 1/3— 6.67% (13.03 mm) (Table 2).

For statistical analysis, the prevalence of multiple roots, multiple root canals, and C-shaped canals in the first mandibular premolars were significantly higher than in the second mandibular premolars ($p < 0.01$). The prevalence of these variations were significantly higher in the male than in the female ($p = 0.04$). However, the prevalence was not significantly different between the right and left mandibular premolars ($p \geq 0.05$).

Discussion

In this study, most of variations in root canal morphology were found in mandibular first premolars of a Thai population. All mandibular second premolars had one root, and their variations in root canal morphology, i.e. multiple root canals or C-shaped canals, were rare. This corresponds to the result from CBCT images in the other study in the Korean population that compared between the first and second mandibular premolars.[20] Our results are also in an agreement to what reported in the comprehensive review of root canal morphology in the mandibular first and second premolars.[5,6] This relatively high variation in the root and root canal morphology in the mandibular first premolar should be recognized in endodontic treatment.

On the contrary, the other CBCT studies in Turkish[26,27] and Saudi[28] populations reported the variation in root canal morphology in the mandibular first and second premolars were low and not different. The prevalence in other nationalities tended to be different and affected by the genome. The variations in root canal morphology especially in the mandibular first premolars is more likely to be found in Asian, European, American, or African[5,6,17,18,20,22–24] at a higher prevalence than in the Middle East (or nearby) population.[26–28] However, the high prevalence at 17—29% of multiple root canals in the mandibular premolars of Iranian has been reported in a systematic review.[29] The prevalence of multiple root canals and C-shaped root canals in the mandibular first and second premolars from CBCT or micro-CT of other nationalities in the recently observational studies have been collected and presented in Table 3.

In our study, the morphological variations in mandibular premolars were not significantly different between the left and the right premolars. The result is confirmed by the results in the previous CBCT studies in German[23] and Turkish.[27] However, our result showed that the prevalence in the male was significantly higher than in the female. This result is in correspondence to what reported in the other studies.[23,27]

Table 3 Prevalence (%) of multiple root canals and C-shaped root canals in mandibular first and second premolars from CBCT or micro-CT in other nationalities reported in recently observational studies.

Study	Nationality	Method	Mandibular first premolar		Mandibular second premolar	
			>1 canal	C-shaped	>1 canal	C-shaped
High prevalence						
Zhang et al.[17]	Chinese	CBCT	22.4%	—	—	—
		Micro-CT	27.3%	—	—	—
Liu et al.[18]	Chinese	Micro-CT	34.8%	—	—	—
Yang et al.[19]	Chinese	CBCT	22.86%	1.14%	—	—
Fan et al.[10]	Chinese	Micro-CT	—	a) with RG 66.5% b) without RG 0%	—	—
Jang et al.[20]	Korean	CBCT	21.2%	3.7% (C2)	1.6%	0%
Ordinola-Zapata et al.[21]	Brazilian	Micro-CT	—	a) with RG 67%	—	—
Pedemonte et al.[22]	Chilean	CBCT	31%	—	5%	—
	Belgium		17%	—	9%	—
Bürklein et al.[23]	German	CBCT	21.9%	—	3.6%	—
Llena et al.[24]	Spanish	CBCT	22%	—	4.5%	—
Low prevalence						
Alfawaz et al.[28]	Saudi	CBCT	3.6%	—	4.4%	—
Bulut et al.[26]	Turkish	CBCT	3.8%	—	1.1%	—
Ok et al.[27]	Turkish	CBCT	6.5%	—	1.5%	—

CBCT—cone-beam computed tomography; C2— C2 C-shaped canal configuration, Micro-CT—micro-computed tomography; RG—radicular groove.

In this study, C-shaped root canals were occasionally found in the mandibular first premolars while the prevalence in the mandibular second premolars was rare. This corresponds to the results from other studies in Chinese, Korean, or Brazilian[10,14,20] especially in the mandibular premolars with the radicular grooves.[10,14] However, the prevalence of C-shaped canals in the mandibular first premolars of Indian population was relatively low.[30] This root-canal anatomical variation should be a concern for endodontic treatment in the mandibular first premolars in a specific population.

C1 and C2 canal configuration were observed in the C-shaped root canals of this Thai population with an approximately equivalent ratio (1:1). In contrast, the C2 configuration was primarily observed in the majority of C-shaped root canals in a Korean population.[20] The canal configuration of C-shaped canals might be diverse and related to the nationality.

In our study, the level of root canal separation in the teeth with multiple root canals was mostly found in the middle portion of the root about 6.5—7 mm from the CEJ. This level of separation is in correspondence to what reported in the other studies.[6] This depth makes localization of the separated canals is more difficult during endodontic treatment. Using a dental operating microscope with illumination might be useful to locate the canal separation at such level.

In conclusion, the mandibular premolars in a Thai population were most likely to have one root. The majority of root canal systems was categorized as the Vertucci's type I (1-1) and V (1—2), with a higher percentage of type V in the mandibular first premolars. The C-shapes root canals and unclassified root canal systems were occasionally found, especially in the mandibular first premolar. In the first and second premolars with multiple root canals, the root canals were usually separated at the middle level of the root. It has been implied that the mandibular first premolars had a higher probability of the variations in root canal morphology than the mandibular second premolars, which dental practitioners must be aware of these unusual morphology during endodontic treatment.

Declaration of Competing Interest

The authors deny any conflicts of interest related to this study.

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