Original Article

Cone-beam computed tomography evaluation of C-shaped root canal system in mandibular second molars in kuwaiti sub-population

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Abstract

Introduction: C-shaped root canal anatomical variations cause challenges in endodontics treatment. This study investigated the prevalence of C-shaped root canals in mandibular second molars in the Kuwaiti population using cone-beam computed tomography (CBCT).

Materials and Methods: CBCT images of sound mature mandibular second molars of 247 Kuwaiti patients were collected from government dental centers. An endodontist and radiologist examined the images to determine the presence of C-shaped canals. They were evaluated at four levels (canal orifice, coronal, middle, and apical thirds of root). Data were collected and statistically analyzed.

Results: One hundred and forty-nine scans and 199 teeth belonging to 62 males and 87 females aged 16–56 years were included. C-shaped canals were found in 26 (13.07%) cases and were more common in females. Females were more likely to have bilateral C-shaped canals ($P < 0.05$). C2 was the most frequent morphology type at the orifice and coronal levels (53.9%) and apical levels (38.5%). An uninterrupted "C" shape was seen in 4 teeth (15.39%). A lingual longitudinal groove with the buccal notch (groove Type II) was seen in 14 teeth (53.85%).

Conclusion: The prevalence of C-shaped canals in the mandibular second molars of a Kuwaiti population was higher than studies performed in the Middle-East population. The morphology type of C-shaped canal in mandibular second molars varied between the root levels. Radicular groove with buccal notches was most frequently located on the lingual side.

Keywords: Cone-beam computed tomography, C-shaped canal, mandibular second molar, radicular groove, root canal morphology

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INTRODUCTION

The primary objective of endodontic treatment is debridement and disinfection of the root canals.[1] A lack of knowledge of root canal morphology may lead to incomplete chemomechanical debridement and failure of root canal treatment.[2] C-shaped canal is one of the most common variations of canal morphology that can be seen along the root length and in some cases may present a thin lingual canal wall. This type of anatomy might require several adjustments on the traditional clinical approach for better outcome results.

Although a C-shaped canal typically occurs in the mandibular second molars,[3] it has also been identified in other teeth, including the maxillary molars[4] and mandibular premolars.[5]

Hertwig's epithelial root sheath controls the radicular morphogenesis which determines the number and shape of the roots.[6] The epithelial sheath curves in a horizontal plane below the cementoenamel junction and fuses in the center, leaving openings for roots. Failure of the epithelial sheath to fuse on the buccal or lingual root surface creates a C-shaped root, containing a C-shaped canal that may appear at any portion of the root canal length. A C-shaped root may also develop because of the coalescence of roots due to cementum deposition.[7]

Melton *et al*.[8] classified C-shaped canals based on their cross-sectional shape, but the differences between categories II and III were not clear. Fan *et al*.[9] used microcomputed tomography and modified Melton's method to analyze the morphology of C-shaped canals in mandibular second molars. According to Fan *et al*.,[9] C1 classification was the most common configuration.

A preoperative conventional radiograph is the only noninvasive method to detect canal morphology.[10,11] Due to its two-dimensional nature and image superimposition, some experts believe that radiographic detection of the complexity of the root canal morphology is not reliable, and the presence of C-shaped canals can only be confirmed during direct access of the pulp chamber.[8,12]

The use of cone-beam computed tomography (CBCT) has been recently increased in dentistry due to its higher accuracy compared to conventional radiographs. Moreover, it can easily diagnose the complex morphology of the teeth such as C-shaped canals and grooves and notches of the external surface of the root.

Several studies of C-shaped root canals in mandibular second molars using CBCT have reported a prevalence of 3.5%–48.7%.[13-22] These studies were conducted in several countries of different ethnicity. The data obtained from these studies may not be applicable in all geographic regions. To date, no study has explored the prevalence of C-shaped root canals in a Kuwaiti population. Therefore, the present study was performed to investigate the prevalence of C-shaped canals in the mandibular second molars of a Kuwaiti population using CBCT and compared with those that occurred in other population.

MATERIALS AND METHODS

This study was approved by the Institutional Review Board of Riyadh Elm University (FPGRP/2020/523/408/401), Riyadh, Saudi Arabia.

Sample collection

A total of 247 CBCT images of mandibular second molars were collected from the radiology departments of four government dental centers in Kuwait. These CBCT scans were performed between January 2019 and September 2020 for various diagnostic purposes. Teeth were selected for inclusion if they belonged to a Kuwaiti citizen aged 16–65 years, had closed root apices, and did not have prior root canal treatment, periapical lesions, resorption, or canal calcification. Only high-quality CBCT images depicting the complete arch or limited view were included. The correlation of age and gender of patients and the tooth position in relation to the frequency of C-shaped canal were determined.

Radiographic evaluation

The CBCT images were retrospectively analyzed by two experienced examiners, an Endodontist and an oral and maxillofacial radiologist, using On-Demand 3D software (Cybermed Inc., Seoul, Korea). Axial, coronal, and sagittal two-dimensional images were displayed on a 32-inch monitor (Hewlett-Packard, California, USA) with a resolution of 1280 × 1024 pixels. Images were carefully analyzed in a dark room after adjusting the magnification and contrast. Examiner alignment was performed to improve inter-examiner reliability, and inter-and intra-examiner reliability was evaluated using statistical methods.

Using the method described by Martins *et al*., we evaluated the CBCT axial reconstructed images for the presence of C-shaped canals in the mandibular second molars at the cross-sectional levels of canal orifices and coronal, middle, and apical thirds of the root.[17] The morphology of C-shaped canals was classified according to Fan *et al*.[9] as follows:

(1) Class I (C1): An interrupted continuous canal of C-shaped cross-section. (2) Class II (C2): Discontinues "semicolon" C-shaped canal configuration. (3) Class III (C3): 2–3 separated canals presented. (4) Class IV (C4): Single round or oval-shaped canal. (5) Class V (C5): No canal lumen is visible.

The C-shaped canals were further classified based on the presence of the radicular groove according to the classification proposed by Shemesh *et al.*[13] into five categories:

(1) Category 1: Lingual groove only. (2) Category 2: Lingual groove and buccal notch. (3) Category 3: Buccal groove only. (4) Category 4: Buccal groove and lingual notch. (5) Category 5: No groove.

Statistical analysis

Statistical analyses were performed using SPSS software, version 22 (IBM, SPSS Inc., Chicago, IL, USA). Categorical variables are presented as numbers and percentages. The prevalence of C-shaped canals with respect to age, sex, and tooth position was also evaluated using the Chi-square-test. Inter- and intra-examiner agreements were evaluated using the Kappa statistic.

RESULTS

A high inter- and intra-examiner agreement for the CBCT reporting (Kappa coefficient 0.96) was observed. Of the 247 CBCT scans identified, 149 met the inclusion criteria and 98 were excluded. The 149 included CBCT scans were from 62 males and 87 females aged 16–56 years. A total of 199 mandibular second molars (103 right-sided and 96 left-sided) were evaluated. There was no difference among gender ($P > 0.764$) or age ($P > 0.35$) groups [Table 1]. A C-shaped canal was observed in 26 scans (13.07%) and was more common in scans of females than males [17 vs. 9 cases, respectively; Table 2]. No significant differences were observed in the presence of C-shaped canals between sides ($P > 0.127$) or in bilateral ($P > 0.697$) between both genders.

Table 3 lists the cross-sectional shape of C-shaped canals at different root levels. C2 type morphology was observed in 53.9% of scans at the orifice and coronal levels and in 38.5% of scans at the apical level [Figure 1]. An uninterrupted "C" shape was observed in 4 teeth [15.39%; Figure 2]. No significant difference was observed in the cross-sectional canal shape between different levels ($P > 0.311$). Moreover, a buccal notch was observed in 14 teeth (53.85%) with a lingual longitudinal groove (groove Type II), and a longitudinal groove (groove Type I) was observed in 6 teeth (23.08%). The difference in groove types was statistically significant [$P < 0.0001$; Table 4 and Figure 1].

Table 1: Distribution of the evaluated teeth in relation to age of patients in the four dental centers

	Tooth location		Age (years)				
	Right (n=103)	Left (n=96)	16-25	26-35	36-45	46-55	>56
Total	199**		29	41	42	24	13
χ^2	1.177				17.575		
P	0.852				0.35		

**Some of the CBCT images were taken for one side only. CBCT: Cone-beam computed tomography

Table 2: Distribution of unilateral and bilateral occurrences of C-shaped canals amongst patients

Gender	C-shaped (number of teeth)			
	Unilateral number of teeth		Total, n (%)	Bilateral number of teeth, n (%)
	Left, n (%)	Right, n (%)		
Male	3 (11.54)	6 (23.08)	9 (43.62)	4 (15.39)
Female	11 (42.31)	6 (23.08)	17 (65.39)	10 (38.47)
Total	14 (53.85)	12 (46.16)	26	14 (53.85)
χ^2	2.331		0.152	
P	0.127		0.697	

DISCUSSION

This retrospective study is the first statistical report investigating the prevalence of C-shaped canal morphology in permanent mandibular second molars of the Kuwaiti population. For this reason, the current study used a CBCT imaging database from patients of a Kuwaiti specialized dental centers. It is more sensitive than clinical and conventional radiographic examination in providing an excellent nondestructive and noninvasive image that detects most of the anatomic variations of the external and internal dental anatomy.[19] In addition, the use of CBCT to detect the location of C-shaped canals may help to avoid creating problems during the endodontic treatment.

C-shaped canal is unique anatomical configuration. It is very common in mandibular second molars because of their higher incidence of root fusion.[23] In our study, the prevalence of C-shaped canal in the mandibular second molar was 13.07%, which is higher than that of the Middle-Eastern population.[13,15,20] Although all previous studies used CBCT to evaluate the canal morphology, they differed in terms of sample size and definition and classification of C-shaped canal. These differences may explain the higher prevalence of C-shaped morphology in our study. The prevalence of C-shaped morphology reported by Janani *et al.*[21] in an Iranian study was slightly higher than us (15.3%) and other studies of the Middle East. The apparent reason was that the prevalence was presented as a percentage

Table 3: Cross-sectional canal shapes of C-shaped canals at different levels

Root level	Type of C-shaped canals												χ^2 for (rest level and type of C-shaped	*P*
	C1		Total, *n* (%)	C2		Total, *n* (%)	C3		Total, *n* (%)	C4		Total, *n* (%)		
	Male	Female		Male	Female		Male	Female		Male	Female			
Orifice	3	4	7 (26.90)	3	11	14 (53.90)	3	2	5 (19.20)	0	0	0 (0.00)	10.513	0.311
Coronal	3	3	6 (23.10)	3	11	14 (53.9)	3	3	6 (23.10)	0	0	0 (0.00)		
Mid-root	5	4	9 (34.60)	2	6	8 (30.8)	2	6	8 (30.80)	0	1	1 (3.90)		
Apical	3	2	5 (19.20)	3	7	10 (38.5)	2	5	7 (26.90)	1	3	4 (15.40)		
χ^2	0.418			0.304			2.219			0.417				
P	0.937			0.959			0.528			0.937				

Table 4: Prevalence distribution of radicular groove in mandibular second molars with C-shaped canals (Shemesh *et al*., 2017 classification)

Type of radicular groove	*n* (%)	χ^2	*P*
Type 1 (Lingual groove)	6 (23.08)	69.112	0.000
Type 2 (Lingual groove and buccal notch)	14 (53.85)		
Type 3 (Buccal groove)	2 (7.70)		
Type 4 (Buccal groove and lingual notch)	3 (11.54)		
Type 5 (None)	1 (3.85)		
Total	26		

of grand totals in molars. In addition, studies including Malaysian (48.7%), German (73.3%), Korean (32.7%–44.5%), and Chinese (41.27%) populations[16,19,22,24,25] reported higher prevalence. In these studies, the prevalence of C-shaped canal in the second molar was presented in comparison with that of the other teeth. Differences in the results of the present and previous studies may be due to differences in sample size, classification system, and method of evaluation.

We found that the C-shaped canals were more often unilateral than bilateral, similar to the results of studies conducted by Wu *et al*.,[26] Alfawaz *et al*.,[15] and Shemesh *et al*.[13] We observed no difference in the prevalence of C-shaped canal between both sides, similar to the studies of Kim *et al*.[27] in Koreans and Zheng *et al*.[28] in a Chinese population. Although we did not find the marked difference of bilateral C-shaped canals among genders, some researchers advise caution to clinicians performing endodontic treatment of homologous molars to rule out bilateral C-shaped canal. This difference in our findings is probably a result of variation in sample size and ethnic background.

In our study, we found C-shaped canals more frequently in females than males, similar to the results of most previous studies.[15,17,22,27,29] This might be related to different morphology and development in men and women, including a smaller jaw and larger teeth in women. However, some studies have found no gender differences.[28,30-32] The gender differences should be interpreted with caution, especially in studies where the study participants have more females than males or there is a difference in ethnicity between males and females.

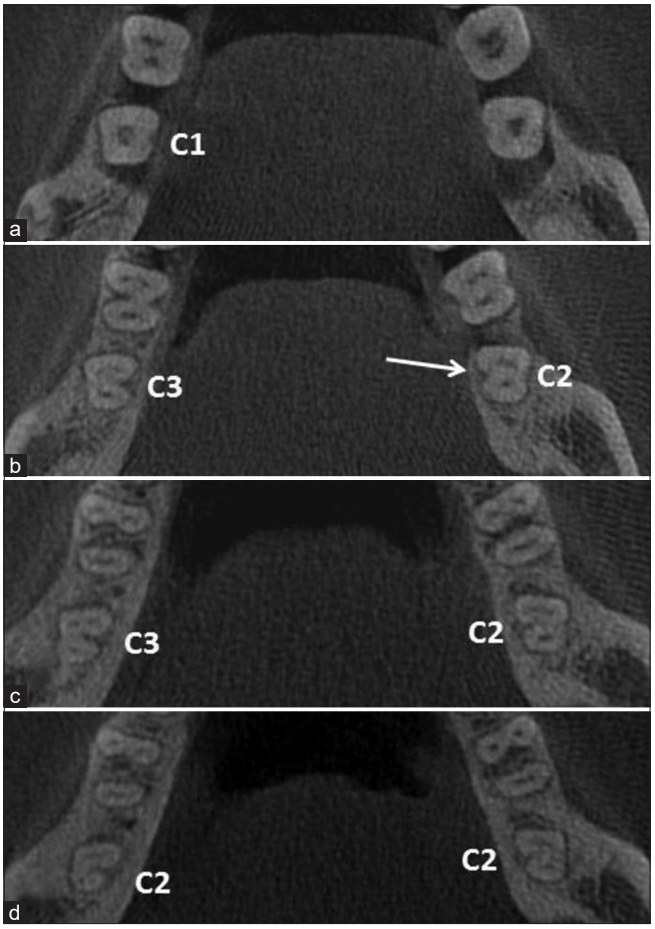

Figure 1: Cone-beam computed tomography axial section of bilateral C-shaped canal of mandibular right and left second molar at different levels with different canal configuration as shown in the canal orifice (a), coronal (b), mid-root (c) and apical (d). Notice the lingual groove with buccal notch of the left molar (arrow)

The CBCT images were divided into five groups based on patient age. C-shaped canals were observed most frequently in individuals aged 26–35 years (11 of 26 scans, 42.3%) than in the older age group. In contrast, Nejaim *et al*.[33] found C-shaped canals to be most common in patients aged 15–24 years, but found no differences between age groups in the logistic regression ($P > 0.05$). The considerable volume of the root canal and pulp chamber are inversely proportional to age due to secondary dentin formation throughout life, which may eventually resulted in almost

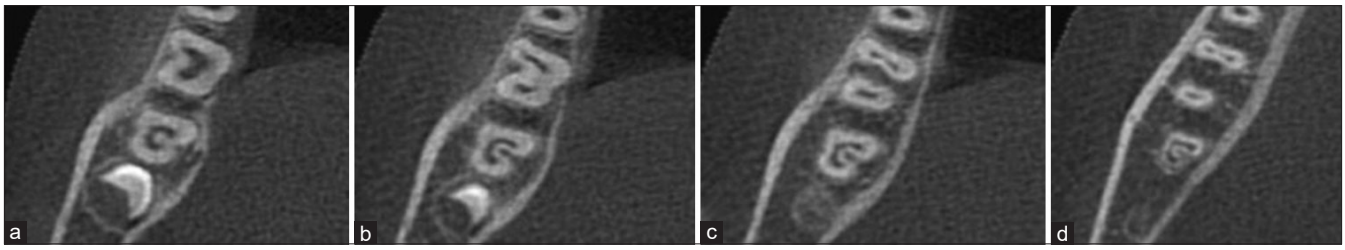

Figure 2: Cone-beam computed tomography axial section of bilateral C-shaped canal of right mandibular second molar with an uninterrupted "C" shape (C1) canal at different levels; the canal orifice (a), coronal (b), mid-root (c) and apical (d)

total pulp obliteration. This might naturally influence the type of the C-canal to vary appreciably at various levels. Martin *et al*.[34] concluded based on a systemic review and meta-analysis that age did not influence the prevalence of C-shaped canals.

The most common type observed in the present study was C2. In contrast, Al-Fouzan[35] reported that C3 was the most common type, while C1 was reported by Fan *et al*.[9] and Tassoker and Sener.[30] Similar to the method described by Zheng *et al*.,[28] we evaluated the mandibular second molars at four root levels, including canal orifice and coronal, middle, and apical third of the root. Only a few previous studies have done that.[32] Type C1, 2, and 3 were seen at all root levels while C4 was observed in the middle and apical levels only. Results of the current study differ slightly from those of Aricioğlu *et al*.[32] who found C3 to be the most common type of canal morphology (28.1%). We found that the most common morphology type in the apical region was C1 (26.5%); in the middle region C2 (32.2%) and in the coronal region it was C3 (43.4%). The differences in these results were due to differences in sample size and studied population. In addition, Zheng *et al*. found that the frequency of C1 and C2 types decreased from the orifice to the apical region, whereas that of C3 and C4 increased.[28]

In the current study, it was noticed that the most frequent type of radicular groove was Type II (lingual groove and buccal notch) followed by Type I (longitudinal groove). Similar findings were reported by Shemesh *et al*.[13] and Kim *et al*.[36] Although the study by Chen *et al*.[37] cannot be directly compared with our study, they found the radicular groove in 69% of cases, more commonly in the lingual half. Care should be taken to avoid root perforation during instrumentation technique as the danger zone is located in the mesiolingual direction.[18]

The present study had a small sample size due to the limited number of specialized government dental centers (four) in Kuwait which was considered a limitation of the study. A future study with larger sample sizes is needed to represent the population better. In addition, *ex vivo* micro-computed tomography technique may acquire high-resolution images for evaluating tiny anatomical details.

CONCLUSION

The prevalence of C-shaped canal in the mandibular second molar in a Kuwaiti population was relatively high (13.07%). It is more common in females than males and more likely to be bilateral than unilateral. Their anatomical configuration varies across different root levels which makes it difficult to clean, fill, and restore. Radicular groove with buccal notches was most frequently located on the lingual side.

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Conflicts of interest

There are no conflicts of interest.

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