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C-Shaped Canal Prevalence and Morphology in Maxillary Molar Teeth: A Cone Beam Computed Tomography Evaluation

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Abstract

Background: The aim was to evaluate the prevalence and morphology of the C-shaped root canal(s) in maxillary molar teeth using cone beam computed tomography (CBCT) images.

Methods: In 2024, the maxillary CBCT volumes of 475 patients were evaluated for C-shaped canal morphology at 3 different axial levels of the molar roots. Classification of the C-shaped canal was done according to the root fusion type, followed by consecutive axial slices with an upper-C (UC)1 or UC2 configuration. The Z-test for proportions in independent groups was used to analyze the differences between location (left and right sides) and tooth (first or second upper molars). The chi-square test was used to compare root fusion types ($P = .05$).

Results: C-shaped canal morphology was found in 4.89% of 797 maxillary molars. C-shaped canal was encountered in 8% of maxillary second and 2% of maxillary first molars. Six different types of UC configurations were observed, with type-A canal structure (23%) having the highest occurrence ($P > .05$). UC1 configuration was more common in the second molars at the middle ($P = .017$) and apical levels ($P = .007$).

Conclusion: Despite the low prevalence, high complexity in morphology requires the attention of clinicians regarding C-shaped maxillary molars to avoid failures and complications.

Keywords: Cone beam computer tomography (CBCT), dentistry, C-shaped maxillary molars

INTRODUCTION

The primary goals of root canal therapy (RCT) include adequate biomechanical shaping, cleaning, and filling of the entire root canal system (RCS) in 3 dimensions. This requires a thorough understanding of root canal morphology and its possible variations, particularly in multi-rooted teeth.[1-4]

Teeth with fused roots have a broad range of internal morphologies and a concealed architecture over the length of the root that complicates the treatment process. This is particularly true for C-shaped canal configurations, which often necessitate adjustments to standard instrumentation, irrigation, and obturation methods.[5-7]

In 1979, Cooke and Fox[8] published the first description of the C-shaped root canal and its clinical implications. After the concept was established, incidence studies in this area increased significantly. A meta-analysis by Martins et al[9] reported that there are numerous studies evaluating the C-shape morphology in mandibular molars; however, few studies have assessed the C-shape morphology in mandibular premolar and maxillary molar teeth. Due to the low number of studies

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on the aforementioned teeth, the relationship between the prevalence and demographic characteristics could not be evaluated.[9] On the contrary, anatomical variations of C-shaped canal morphologies have been investigated by numerous studies. Case studies have demonstrated that the anatomy of maxillary C-shaped molars is quite complex, and there are clear distinctions between the C-shaped configurations of maxillary and mandibular molar teeth.[10-12]

C-shaped canal configurations have been evaluated with many radiographic methods including micro-computed tomography (CT), spiral CT, and recently con ebeam computed tomography (CBCT).[5-8,13] Micro-CT is considered the gold standard method for the evaluation of C-shape morphology; however, it cannot be employed in the clinic. Therefore, high-resolution cross-sectional CBCT images may be utilized for evaluating root canal anatomies, providing precise root canal configurations at a low radiation dose and cost.[1415] Therefore, this study aimed to evaluate the prevalence and morphology of C-shaped root canal(s) in maxillary molar teeth using CBCT images. The null hypothesis of the study was that no C-shaped canal configuration could be observed in maxillary molars.

Material and Methods

This study was approved by the Ethics Committee of the Ege University (Approval no: 2021/22-2.1T/33, Date: February 22, 2021). Formal consent was not required for the present study because only radiographic images were analyzed. However, all patients at our clinic provide general consent that their data may be used anonymously for research purposes.

The maxillary CBCT volumes of 2024 patients were selected from the image archive obtained between January 2019 and May 2020 in the Department of Oral and Maxillofacial Radiology. Maxillary CBCT volumes of 475 patients with mature molar roots and closed apices were included in the study. Teeth with root canal treatment and/or restorations that can cause beam hardening artifacts, and teeth with internal and/or external root resorptions were excluded. Images of 797 maxillary molar teeth (460 first and 337 second molars) of 475 patients (297 females, 178 males) were evaluated retrospectively for the presence of C-shape canal morphology. Images had been previously obtained with the Carestream (Cs) Kodak 9000 3D (Onex Inc., New York, USA) CBCT device at 70 kV, 10 mA, and 10.8 exposure time, using a 76 μm isotropic voxel size. CS 3D imaging software (version 3.10.9) was used to process and recreate all CBCT images.

Maxillary molar roots were evaluated at 3 axial root levels:

(1) 2 mm below the cemento-enamel junction—the coronal level,
(2) 2 mm above the anatomic apex—the apical level, and
(3) the halfway point between the coronal and apical levels—the middle level.

The root and canal configurations of maxillary molar teeth were classified separately based on 2 different classification systems as suggested by Martins et al.[5] First, the root was analyzed with regard to the position of the root fusion. Accordingly, type A was identified as a fusion between the mesiobuccal and palatal root canals, while type B was a fusion between the mesiobuccal and distobuccal root canals with 2 sub-types (B1 and B2); type C was identified as a fusion between the distobuccal and palatal root canals; type D was identified as the presence of a sizable palatal root canal forming a semilunar; and type E was a fusion between the 3 roots with 2 sub-types (E1 and E2) (Figure 1).

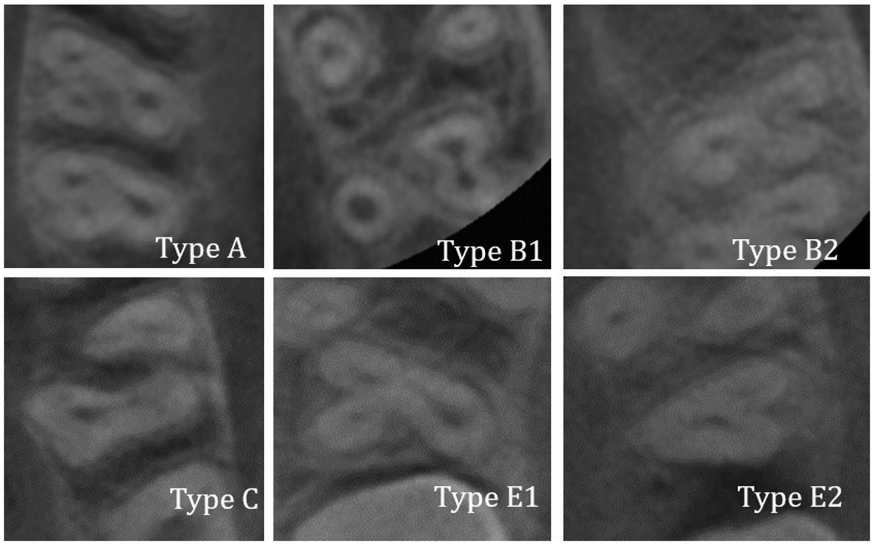

Figure 1. Axial views of different types of C-shaped canals.

Figure 2. Axial views of different UC classifications of C-shaped canals.

The C-shaped canal configuration was classified using the upper-C (UC) classification system.[5] The UC1 was described as a continuous huge C-shaped canal system; UC2 as a continuous C-shaped canal with 2 major canal lumens at the extremities joined by a wide isthmus; UC3 as 2 separate root canals; UC4 as a single round or oval root canal; and UC5 as no canal lumen (Figure 2). Molar roots were evaluated according to both classification systems, and findings were recorded separately for 3 axial levels. Two oral radiologists and 1 endodontist with approximately 3-25 years of experience evaluated the images separately. Maxillary molar teeth with 2 or 3 fused roots plus with UC1 or UC2 isthmus anatomy in 3 consecutive axial slices at any root level were accepted as having a C-shaped canal configuration.

The percentage of each canal configuration was calculated using descriptive statistics, as was the range for the true population proportion, to a confidence level of 95%. The Z-test for percentages was used to analyze the differences in C-shaped root canal configurations for comparison of left and right maxillary molars as well as first and second maxillary molars. The chi-square test was used for the comparisons of root fusion types ($P = .05$). Interobserver reliability between 3 researchers was analyzed using the Cohen's kappa test.

RESULTS

The mean age of 475 patients included in the study was 31.4 ± 15.30, while the mean age of 33 patients with C-shaped maxillary molar teeth was 28.69 ± 15.36.

Prevalence of C-shaped Canals in First and Second Maxillary Molar Teeth

Among the 797 maxillary molar teeth studied, 4.8% (n = 39) were found to have a C-shaped canal morphology. Therefore, the null hypothesis was rejected. Further analysis revealed that out of the 297 female patients, a total of 493 teeth were evaluated, and 4.8% (n = 24) were identified as having a C-shaped canal configuration. Similarly, among the 178 male patients, 304 teeth were evaluated, and 4.9% (n = 15) showed this morphology. It is important to note that there was no statistically significant difference in the prevalence of C-shaped canals between the genders ($P > .05$).

Upon closer inspection, the study revealed that 2.3% (n = 11) of the 460 first molars displayed a C-shaped canal morphology, whereas a higher proportion of 8.3% (n = 28) was observed among the 337 second molars. This dissimilarity in the occurrence of C-shaped canals between the first and second maxillary molars was found to be statistically significant ($P < .001$) (Table 1).

Distribution of C-Shape Morphologies Among Maxillary Molars

The most common types of fusion for maxillary molar teeth with C-shaped canal morphology were type C (28%) and type B (28%), while type D was never encountered. The prevalence of the second molar was higher in all fusion types except type C (Table 2).

Evaluation of the C-shaped canal configuration among maxillary molar teeth revealed that UC1 (56.4%) and UC2 (41%) configurations were most frequent at the coronal level, whereas UC3 was predominantly observed at the middle (48.7%) and apical (61.5%) root levels. Upper class 4 configuration was not present at the coronal and middle levels, and UC5 was not seen at any axial level.

Distribution of C-Shape Morphologies According to Jaw Side, Tooth Number, and Axial Root Level

No significant difference was found between right and left maxillary molars regarding the prevalence of C-shaped canal configurations ($P > .05$) (Table 3). However, UC1 was

Table 1. Incidence of First and Second Maxillary Molars Showing C-Shaped Canal Morphology

	C-Shaped Morphology (n)	Total (n)	Percentage (%)	Comparison Between Incidences*
First Molar	11	460	**2.3**	$P = .00025$
Second Molar	28	337	**8.3**	

*Chi-square test was used.

Table 2. Distribution of C-Shaped Canal by Types in the First and Second Maxillary Molars

Type of Root Fusion	First Molar (%)	Second Molar (%)	All Molars (%)
Type A	0	32	23
Type B1	9	18	15
Type B2	0	18	13
Type C	91	3.3	28
Type D	0	0	0
Type E1	0	18	13
Type E2	0	10.7	8

Table 3. Incidence of Right and Left Maxillary Molars Showing C-Shaped Canal Morphology

	Right Molars	Left Molars	Total	Comparison Between Incidences*
Molars with C-shaped teeth	19	20	39	*P* = .544
Total	361	436	797	

*Chi-square test was used.

significantly more common in the left maxillary molars at the middle level, while UC2 was more common in the right molars at the middle level (Table 4). When the first and second molars were compared according to UC classification, it was observed that UC1 was significantly more common in the middle and apical levels of the second molars ($P < .05$) (Table 5).

Interobserver Agreement

Interobserver kappa coefficients of UC and the C-shaped canal type classifications were determined as 0.760 and 0.832, respectively.

DISCUSSION

C-shaped canals are frequently encountered in mandibular molar teeth. Accordingly, the prevalence and factors for their occurrence have been intensively discussed.[7,16-25] On the contrary, relatively few studies have evaluated the C-shaped canal configuration of maxillary molars, reporting a wide range of prevalence (0.8-7.9%) (Table 6).[5,26-31] It has been concluded that the variation in prevalence may be due to ethnic origin, sample size, image quality, the mean age of subjects, and observer bias. Moreover, due to the acceptance of a wide variety of methodologies adopted in various studies, it is not possible to make a comparison regarding the prevalence of C-shaped morphology for maxillary molars. In order to eliminate the inconsistency, studies with similar methodologies were used for the comparison of our findings.

Table 4. Distribution of Isthmus Classification in the Axial Middle Third Between First and Second Molars

Isthmus Classification	Molar	Count (n)	Within Middle Level (%)	Within Molars (%)	Total (%)
UC1	First molar	1	9.1	9.1	2.6
	Second molar	10	90.9 (*P* = .017)	35.7	25.6
	Total	11	100.0	28.2	28.2
UC2	First molar	3	33.3	27.3	7.7
	Second molar	6	66.7	21.4	15.4
	Total	9	100.0	23.1	23.1
UC3	First molar	7	36.8	63.6	17.9
	Second molar	12	63.2	42.9	30.8
	Total	19	100.0	48.7	48.7
Total	First molar	11	28.2	100.0	28.2
	Second molar	28	71.8	100.0	71.8
	Total	39	100.0	100.0	100.0

Table 5. Distribution of Isthmus Classification in the Axial Middle Third Between Right and Left Molars

Isthmus Classification	Molar	Count (n)	Within Middle Level (%)	Within Molars (%)	Total (%)
UC1	Right molars	3	27.3	15.0	7.7
	Left molars	8	72.7 (*P* = .025)	42.1	20.5
	Total	11	100.0	28.2	28.2
UC2	Right molars	7	77.8 (*P* = .028)	35.0	17.9
	Left molars	2	22.2	10.5	5.1
	Total	9	100.0	23.1	23.1
UC3	Right molars	10	52.6	50.0	25.6
	Left molars	9	47.4	47.4	23.1
	Total	19	100.0	48.7	48.7
Total	Right molars	20	51.3	100.0	51.3
	Left molars	19	48.7	100.0	48.7
	Total	39	100.0	100.0	100.0

The variation of ethnic origin as regards the prevalence of C-shaped canal morphology in mandibular molars is a major factor.[19,25,32] A single study that evaluated the prevalence of C-shaped maxillary molars in the Turkish population reported a similar prevalence ratio (3%).[28]

The percentage of C-shaped canal morphology for maxillary molar teeth found in the present study (4.8%) was higher than that of comparable studies, except for the study of Jo et al.[26] Although the overall prevalence of C-shaped canals reported in different studies for maxillary molars was volatile, the prevalence was higher in maxillary second molars in all studies, which is in accordance with the findings of the present study. While differences in ethnic origin are an undeniable factor, it is well agreed that an increase in the mean age of the subjects decreases the probability of C-shape morphology due to the increase in secondary dentin thickness.[26,33] However, one of

Table 6. Voxel Sizes of Images Used in Previous Studies in Order to Evaluate the Prevalence of C-Shaped Canals in Maxillary Molars

Research	Voxel Size (mm)	First Molar, n (%)	Second Molar, n (%)	Total, n (%)
Jo et al (2016)[26]	0.3	1786 (0.8)	1767 (2.7)	3553 (1.8)
Martins et al (2016)[5]	0.2	928 (1.1)	1299 (3.8)	2227 (2.6)
Mashyakhy et al (2019)[28]	0.25	354 (0.6)	372 (1.1)	726 (0.8)
Köse et al (2021)[27]	0.2	709 (1)	739 (4.9)	1448 (3)
Qian et al (2022)[29]	0.125-0.25	1488 (0.54)	1547 (5.24)	3035 (2.93)
Abdalrahman et al (2022)[25]	0.125-0.25	None	369 (7.9)	369 (7.9)
This study	0.076	460 (2.3)	337 (8.3)	797 (4.8)

the main reasons that has been overlooked for the discrepancy among reported prevalence is the quality of the CBCT images, which is closely related to the voxel size, as well as the criteria used for the classification of C-shape morphology.

Since CBCT was used for the detection of C-shaped canals in this study, only the results of studies that had used CBCT were considered for comparison. Cone-beam computed tomography was preferred because it provides high-quality images with a relatively low dose. The American Academy of Oral and Maxillofacial Radiology (AAOMR) and the American Association of Endodontists (AAE) emphasized the importance of using a limited field of view and, accordingly, the smallest voxel size for CBCT imaging for endodontic diagnosis.[34] As the voxel dimension decreases, the image resolution increases, which in turn increases the detection of small details.[35] It is noteworthy that previous studies investigating the prevalence of C-shaped canals in maxillary molar teeth have used CBCT images with voxel sizes ranging from 125 to 300 μm. To the authors' knowledge, there is no study that has used high-resolution images with a voxel size of 76 μm for the evaluation of C-shaped canals in maxillary molar teeth. In accordance with the high prevalence rate of C-shaped maxillary molars found in the present study, it has been proved that the accuracy of detection of canal lumens connected with a thin isthmus (particularly UC2) increases as the voxel resolution increases, which in turn leads to an increase in prevalence.

The lack of a common classification of C-shape morphology for maxillary molars is another reason for obtaining variable prevalences in different studies. Martins et al[5] have evaluated the prevalence of C-shaped morphology in maxillary molars at 5 axial sections and were the first to define a C-shape canal in maxillary molars. On the other hand, based on a different classification system developed by Köse et al[27] and later modified by Yang et al,[30] maxillary molar teeth were considered to have C-shaped morphology according to the fused root canals that formed a C-shape at any axial root level. In the present study, we first evaluated the presence of a root fusion, and then C-shaped canal morphology was considered to be present whenever 3 consecutive axial CBCT slices showed a continuous C-shape. By performing a 2-stage assessment, a single isthmus with a C-shaped canal was eliminated, which could easily be mistaken as C-shape morphology in images with larger voxel size (high slice thickness). Unlike many other studies, the upper-C classification was not used as a single criterion but the evaluation of 3 consecutive axial sections was also included. Since we required 3 consecutive axial slices with C-shape with 76-μm voxel size images, a total of 228-μm root thickness was evaluated and then accepted as C-shape canal morphology. The selection of the smallest voxel size and thus, the minimum slice thickness is important for the success of endodontic therapy, particularly for maxillary molars with C-shaped morphology that does not follow the original canal. Accordingly, a commonly accepted C-shaped morphology definition and image resolution for the evaluation of maxillary molar teeth should be determined for better accuracy and comparison of further/future studies.

Consistent with the findings of Martins et al[5] all C-shaped canal types, except type C, were more frequent in second molars in our study group. Similar to the reported findings for mandibular molar teeth with C-shaped canal morphology, maxillary molar teeth showed higher rates for C-shaped morphology at the coronal level and higher UC1 and UC2 configurations.[35] Therefore, it may be recommended that caution should be exercised in the evaluation of the coronal regions of maxillary molar teeth.

Evaluation of a single population may be considered as the limitation of this study. However, the lack of standardized criteria used to define the C-shape morphology for maxillary molar teeth is a factor that applies to all similar studies. Even so, the use of high-resolution images with a voxel size of 76 μm is one of the distinguishing features of this study, which is in accordance with the recommendations of AAOMR and AAE for the accuracy of endodontic diagnosis.[34]

In conclusion, maxillary C-shaped molars have high anatomic variations, and maxillary second molars with a C-shaped canal anatomy show a higher prevalence than maxillary first molars. Recognition of anatomic variations and complexities is required to provide technical modifications during root canal treatment to ensure higher success rates and long-term achievement.

Availability of Data and Materials: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee Ege University (Approval no: 2021/22-2.1T/33, Date: February 22, 2021).

Informed Consent: Written informed consent was obtained from all patients who participated in this study.

Peer-review: Externally peer-reviewed.

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REFERENCES

1. Peters O. Current challenges and concepts in the preparation of root canal systems: a review. *J Endod*. 2004;30(8):559-567. [CrossRef]

2. Schilder H. Cleaning and shaping the root canal. *Dent Clin North Am*. 1974;18(2):269-296. [CrossRef]
3. Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. *Endod Topics*. 2005;10(1):3-29. [CrossRef]
4. Walton RE. Current concepts of canal preparation. *Dent Clin North Am*. 1992;36(2):309-326. [CrossRef]
5. Martins JNR, Mata A, Marques D, Anderson C, Caramês J. Prevalence and characteristics of the maxillary C-shaped molar. *J Endod*. 2016;42(3):383-389. [CrossRef]
6. Tian XM, Yang XW, Qian L, Wei B, Gong Y. Analysis of the root and canal morphologies in maxillary first and second molars in a Chinese population using cone-beam computed tomography. *J Endod*. 2016;42(5):696-701. [CrossRef]
7. Zhang Q, Chen H, Fan B, Fan W, Gutmann JL. Root and root canal morphology in maxillary second molar with fused root from a native Chinese population. *J Endod*. 2014;40(6):871-875. [CrossRef]
8. Cooke HG, Cox FL. C-shaped canal configurations in mandibular molars. *J Am Dent Assoc*. 1979;99(5):836-839. [CrossRef]
9. Martins JNR, Marques D, Silva EJNL, Caramês J, Mata A, Versiani MA. Prevalence of C-shaped canal morphology using cone beam computed tomography – a systematic review with meta-analysis. *Int Endod J*. 2019;52(11):1556-1572. [CrossRef]
10. Yılmaz Z, Tuncel B, Serper A, Calt S. C-shaped root canal in a maxillary first molar: a case report. *Int Endod J*. 2006;39(2):162-166. [CrossRef]
11. Martins JNR, Quaresma S, Quaresma MC, Frisbie-Teel J. C-shaped maxillary permanent first molar: a case report and literature review. *J Endod*. 2013;39(12):1649-1653. [CrossRef]
12. Liu CH, Hsieh SC, Wang HH. Apical microsurgery of C-shaped maxillary first molar: A case report. *J Dent Sci*. 2021;16(3):1035-1036. [CrossRef]
13. Jin GC, Lee SJ, Roh BD. Anatomical study of C-shaped canals in mandibular second molars by analysis of computed tomography. *J Endod*. 2006;32(1):10-13. [CrossRef]
14. Maret D, Peters OA, Galibourg A, et al. Comparison of the accuracy of 3-dimensional cone-beam computed tomography and Micro–Computed tomography reconstructions by using different voxel sizes. *J Endod*. 2014;40(9):1321-1326. [CrossRef]
15. Zhang D, Chen J, Lan G, et al. The root canal morphology in mandibular first premolars: a comparative evaluation of cone-beam computed tomography and micro-computed tomography. *Clin Oral Investig*. 2017;21(4):1007-1012. [CrossRef]
16. Ahmed HA, Abu-bakr NH, Yahia NA, Ibrahim YE. Root and canal morphology of permanent mandibular molars in a Sudanese population. *Int Endod J*. 2007;40(10):766-771. [CrossRef]
17. Al-Fouzan KS. C-shaped root canals in mandibular second molars in a Saudi Arabian population. *Int Endod J*. 2002;35(6):499-504. [CrossRef]
18. Al-Qudah AA, Awawdeh LA. Root and canal morphology of mandibular first and second molar teeth in a Jordanian population. *Int Endod J*. 2009;42(9):775-784. [CrossRef]
19. Manning SA. Root canal anatomy of mandibular second molars. Part I. *Int Endod J*. 1990;23(1):34-39. [CrossRef]
20. Neelakantan P, Subbarao C, Subbarao CV, Ravindranath M. Root and canal morphology of mandibular second molars in an Indian population. *J Endod*. 2010;36(8):1319-1322. [CrossRef]
21. Peiris HRD, Pitakotuwage TN, Takahashi M, Sasaki K, Kanazawa E. Root canal morphology of mandibular permanent molars at different ages. *Int Endod J*. 2008;41(10):828-835. [CrossRef]
22. Weine FS. The C-shaped mandibular second molar: incidence and other considerations. Members of the Arizona Endodontic Association. *J Endod*. 1998;24(5):372-375. [CrossRef]
23. Weine FS, Pasiewicz RA, Rice RT. Canal configuration of the mandibular second molar using a clinically oriented in vitro method. *J Endod*. 1988;14(5):207-213. [CrossRef]
24. Zheng Q, Zhang L, Zhou X, et al. C-shaped root canal system in mandibular second molars in a Chinese population evaluated by cone-beam computed tomography. *Int Endod J*. 2011; 44(9):857-862. [CrossRef]
25. Abdalrahman K, Talabani R, Kazzaz S, Babarasul D. Assessment of C-shaped canal morphology in mandibular and maxillary second molars in an Iraqi subpopulation using cone-beam computed tomography. *Scanning*. 2022;2022:4886993. [CrossRef]
26. Jo HH, Min JB, Hwang HK. Analysis of C-shaped root canal configuration in maxillary molars in a Korean population using cone-beam computed tomography. *Restor Dent Endod*. 2016;41(1):55-62. [CrossRef]
27. Köse E, Ak R. Evaluation of C-shaped canal configuration in maxillary molars: a retrospective cone-beam computed tomography study. *Clin Exp Health Sci*. 2016;11(3):444-448. [CrossRef]
28. Mashyakhy M, Chourasia HR, Jabali A, Almutairi A, Gambarini G. Analysis of fused rooted maxillary first and second molars with merged and C-shaped canal configurations: prevalence, characteristics, and correlations in a Saudi Arabian population. *J Endod*. 2019;45(10):1209-1218. [CrossRef]
29. Qian Y, Li Y, Song J, Zhang P, Chen Z. Evaluation of C-shaped canals in maxillary molars in a Chinese population using CBCT. *BMC Med Imaging*. 2022;22(1):104. [CrossRef]
30. Yang ZP, Yang SF, Lee G. The root and root canal anatomy of maxillary molars in a Chinese population. *Endod Dent Traumatol*. 1988;4(5):215-218. [CrossRef]
31. Zhang R, Wang H, Tian YY, Yu X, Hu T, Dummer PMH. Use of cone-beam computed tomography to evaluate root and canal morphology of mandibular molars in Chinese individuals. *Int Endod J*. 2011;44(11):990-999. [CrossRef]
32. Mahmood M, Talabani R, Baban M. Age estimation using lower permanent first molars on a panoramic radiograph: a digital image analysis. *J Forensic Dent Sci*. 2015;7(2):158-162. [CrossRef]
33. American Association of Endodontists, American Academy of Oral and Maxillofacial Radiology. Use of cone-beam computed tomography in endodontics Joint Position Statement of the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2011;111(2):234-237. [CrossRef]
34. Bauman R, Scarfe W, Clark S, Morelli J, Scheetz J, Farman A. *Ex vivo* detection of mesiobuccal canals in maxillary molars using CBCT at four different isotropic voxel dimensions. *Int Endod J*. 2011;44(8):752-758. [CrossRef]
35. Fan B, Cheung GSP, Fan M, Gutmann JL, Bian Z. C-shaped canal system in mandibular second molars: Part I—Anatomical features. *J Endod*. 2004;30(12):899-903. [CrossRef]