Journal of Iranian Dental Association (JIDA)

Original Article

Evaluating Root Canal Morphology in Mandibular Second Molars of an Iranian Population Using Cone-Beam Computed Tomography

Hadi Assadian[1], Amir Hedayatian[2], Marzieh Pishbin[3] *

[1] Assistant Professor, Department of Endodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, IR Iran
[2] Undergraduate Student, Department of Endodontics, School of Dentistry, Shahed University, Tehran, IR Iran
[3] Postgraduate Student, Department of Endodontics, School of Dentistry, Islamic Azad University Isfahan (Khorasegan) Branch, IR Iran

*** Corresponding Author:** Marzieh Pishbin , **Email:** dr.mrz.pishbn@gmail.com
DOI:10.34172/jida.A-10-1528-1

Abstract

Background and Aim: Root canal morphology impacts endodontic success, yet data on mandibular second molars in the Iranian population is limited. This study aims to evaluate their root canal anatomy using Cone-Beam Computed Tomography, enhancing treatment planning and clinical outcomes in endodontics.
Materials and Methods: This cross-sectional study utilized a convenient sampling method to analyze 221 Cone-Beam Computed Tomography (CBCT) images of mandibular second molars from an initial 718 scans taken between October 2013 and May 2014. Exclusions were made for previous root canal treatment, root resorption, periapical pathosis, calcified canals, post and core restoration, open apex, and low image quality. The study assessed root and canal numbers, canal shapes using the Vertucci classification, and C-shaped canals per the modified Melton method, while also evaluating the effects of age, gender, and bilaterality. The data were analyzed using the marginal homogeneity test and the exact Chi-Square test. The statistical software employed in this study was SPSS Software (Version 23.0, IBM Corp., USA) for Windows.
Results: Most second mandibular molars had two roots (81.5%), with C-shaped roots observed in 6.9% of cases. Among those with separated roots, the predominant canal type in the distal root was Type I of the Vertucci classification (98%), followed by Type V (1.7%) and Type II (0.3%). The mesial root exhibited more variation, with Type III being the most common configuration (40.6%). Most cases on both sides had the same number of roots (81.6%), and two-rooted second molars predominantly had one canal in the distal root (95.6%). In both genders, two roots were found in most cases (male: 62.7%, female: 80.9%), and 80% of individuals over 50 had two-rooted second molars, with the highest prevalence of C-shaped roots in this age group (13.3%).
Conclusion: The mandibular second molars in the studied Iranian population predominantly had two roots, with Type I being the most common configuration in the distal root (98%) and Type III in the mesial root (40.6%). The prevalence of "C-shaped canals was low (5.1%), highest in those over 50 (13.3%). No significant differences were found in root shape between genders or sides of the mandible.
Key Words: Root Canal Morphology, Mandibular Second Molars, Cone-Beam Computed Tomography (CBCT), Endodontics, Dental Anatomy, Root Canal Configuration.

Received: 8 July 2025 | **Accepted:** 9 Oct 2025 | **ePublished:** Summer and Autumn 2025; Vol. 37, No. 3-4

Introduction

Root canal morphology plays a critical role in the success of endodontic treatments (1). Understanding the variations in root canal anatomy is essential for effective cleaning, shaping, and obturation of the root canal system (2). The root canal system has a wide range of anatomical variations in terms of the presence of extra roots, extra root canals, conical roots, fins, isthmuses, loops, as well as unique morphologies such as S-shaped and C-shaped canals which can complicate the stages of endodontic treatment, from canals identification to obturation (3, 4). Hence, it is important to comprehend root canal morphologic variations in all tooth types before treatment (3, 5, 6). Variations in

root canal anatomy of the mandibular second molar have been documented for several populations, it is also well established that root canal anatomy has a definitive racial influence, thereby necessitating the identification of root canal morphologies of different races (7). Previous studies have highlighted significant differences in root canal morphology across different populations, emphasizing the need for region-specific data (6).

Numerous studies have investigated the root canal morphology of mandibular second molars that show these teeth usually have two roots with three root canals, two canals in mesial root and one in distal (5). While studies conducted in mixed populations demonstrate a predominance of Vertucci's type II canal configuration in the mesial roots, two-rooted second molars of Asians appear to show Vertucci's type IV in the mesial roots and type I in the distal (7). Also, another anatomic variation is such as fused roots with buccal or lingual grooves or with one single canal and C-shaped pattern (with a deep buccal or lingual groove) (5). The "C"-shaped root is thought to be caused by a defect in the fusion of the Hertwig's sheath or by the deposition of cementum over time (1). This variation is characterized by a fin or web connecting individual root canals, forming a 'C' shape at the root canal orifice (8). C-shaped configuration have reported with wide range of incidence (2.7-52%) (6). With more frequent in the Asian population or white race. This variation seems to be associated with their ethnicity (9).

Preoperative imaging techniques such as traditional radiography, micro-CT, and Cone Beam Computed Tomography (CBCT) are commonly used before root canal treatment to provide insights into root canal morphology (3, 9, 10). While traditional radiographs often fail to detect anatomical anomalies due to their two-dimensional nature (11), micro-CT offers detailed,

accurate images of root canal systems but is limited to ex-vivo studies due to high radiation doses and longer scan times (3, 6, 12). Recently, CBCT has been successful in providing three-dimensional analyses for evaluating complex root canal morphologies and aiding in treatment planning, especially for challenging cases like "C"-shaped canals (1, 3). CBCT has also facilitated studies across diverse populations, highlighting variations influenced by race, age, sex, ethnicity, and geography (1). However, there is limited data available on the Iranian population concerning root canal morphology of different tooth types.

This study aims to address the gap in the literature by analyzing the root canal morphology of mandibular second molars in an Iranian population using CBCT. The objectives of this study are to determine the prevalence of different root canal configurations and to compare these findings with those reported in other populations. It was hypothesized that the root canal morphology of mandibular second molars in the Iranian population exhibit unique characteristics that differ from those reported in other populations.

Materials and Methods

1. Ethical considerations

This cross-sectional research was approved by the Research Ethics Committee of School of Dentistry, Shahed University, Tehran, Iran. (IR.SHDU.Dent.Res.1397070).

2. Sample size calculation

A convenient sampling approach was employed to ensure standardization in image acquisition characteristics.

Consequently, all CBCT images taken for various diagnostic purposes between October 2013 and May 2014 at a private oral and maxillofacial radiology clinic were included in the study (n=718). A number of 497 CBCT images were excluded from the study due to the following criteria: presence of previous root canal treatment, root resorption, periapical pathosis, calcified canals, post and core restoration, open apex, and low quality of the images.

Ultimately, 221 CBCT images comprising 319 second mandibular molars were included in the analysis.

3. Image acquisition and analysis

All CBCT images used in this study were prepared using the NewTomVG system (QRsrl, Verona, Italy). The scanned images, taken at a voltage of 110 KVP, were examined in two formats: full and zoom. In the zoom format, the parameters were FOV 6.512 cm, 8 mA, voxel size 0.24 mm, and slice thickness 1 mm. In the full format, the parameters were 5 mA, FOV 1116 cm, and voxel size 0.300 mm. The presence of each tooth was initially confirmed from the panoramic view in the CBCT images. Then, using the Multiplanar Reconstruction (MPR) view available in

the NNT viewer software, the pulp chamber floor was identified (Figure 1). It should be noted that in this view, all three sagittal, axial, and coronal sections can be seen. Adjustments in one section would simultaneously alter the others to minimize errors. Images were subsequently prepared with slice intervals of 0.24-0.3 mm in the sagittal, axial, and coronal planes. The sections of the mandibular plane were moved from coronal to apical in the sagittal view, with all cases observed and reported. This study examined the number of roots, the number of canals in each root, and the shape of the canals according to the Vertucci classification (13), as well as C-shaped canals according to the modified Melton's method (14,15). Additionally, the effects of age, gender, and bilaterality on these cases were evaluated.

4. Statistical analysis

The marginal homogeneity test and the exact Chi-Square test were employed to analyze the data in this study. SPSS (Version 23.0, IBM Corp., USA) for Windows was utilized as the statistical software tool for the statistical analyses.

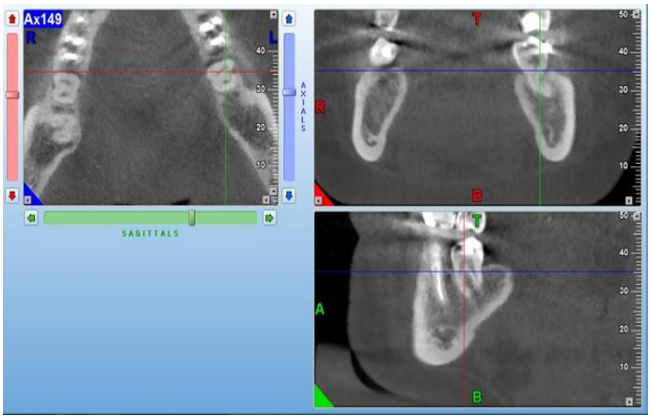

Figure 1. CBCT evaluation in multiplanar reconstruction (MPR) view generated with NNT Viewer software, illustrating the position of the radicular-coronal pulp interface.

Results

In total, 319 mandibular second molar teeth were evaluated from 221 CBCT images. Among these images, 156 were from male patients (48.9%) and 163 from female patients (51.1%). One hundred and twenty-three patients (55.6%) had second molar teeth on one side of the mandible, while 98 patients (44.3%) had second molar teeth on both sides.

Most of the second mandibular molars had two roots (81.5%). Other morphologies included one root (0.9%), three roots (2.2%), and four roots (0.9%). Some teeth had two separate roots that fused in the apical third (7.2%), and one tooth exhibited a single root that divided into two roots in the middle. Additionally, C-shaped roots were observed in 6.9% of the cases.

For second mandibular molars with separated roots, the dominant variety of canals in the distal root was Type I according to Vertucci's classification (98%), followed by Type V (1.7%) and Type II (0.3%). Mesial root canals showed more variation; the most common configuration was Type III (40.6%), followed by Type I (20.1%), Type V (14.7%), Type II (11.9%), Type IV (8.5%), and Type VI (2.4%).

In addition to these canal configuration systems, two new configurations were observed which are not mentioned in Vertucci's classification: the 2-1-2-1 anatomy (1.4%) and the 1-2-1-2-1 anatomy (0.3%).

1. Bilaterality

In cases where second molars were observed on both sides of the mandible, the majority (81.6%) had the same number of roots. Most of these cases (71.4%) had two roots on both sides, while a smaller portion (5.1%) exhibited C-shaped root variations (Table 1, Figure 2). In only one instance, the left second molar had two roots, while the right one showed a C-shaped variation. The similarity in root shape on both sides of the jaw was analyzed using the marginal homogeneity test (p-value: 0.452), which indicated no significant difference in root shape between sides. For second molars with two roots on both sides of the mandible, the distal root most commonly contained a single canal (95.6%), with only a small percentage (4.4%) showing variations between the right and left sides. Specifically, 3.3% of these cases exhibited a type I canal on one side and a type V canal on the other (Table 2). Overall, there was no significant difference in the shape of distal canals on either side of the jaw. However, greater variation was noted in the mesial root. Although similar canal types were found in the mesial roots on both sides in most cases (74.7%), with type III canals being the most prevalent (33%), followed by type I (16.5%), there were instances of

Table1. Frequency of different root configuration types

Root shape	Tooth side (number/percentage)		
	Total	Left	Right
One root	3 (.9%)	0 (.0%)	3 (2.0%)
Two roots	260 (81.5%)	136 (80.5%)	124 (82.7%)
Three roots	7 (2.2%)	4 (2.4%)	3 (2.0%)
Four roots	3 (.9%)	2 (1.2%)	1 (.7%)
2-1 root	23 (7.2%)	13 (7.7%)	10 (6.7%)
C-shape root	22 (6.9%)	13 (7.7%)	9 (6.0%)
1-2-1 root	1 (.3%)	1 (.6%)	0 (.0%)
Total	319	169	150
	100.0%	**100.0%**	**100.0%**

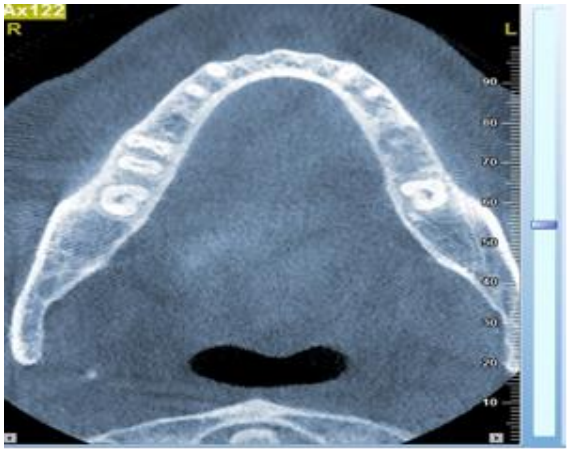

Figure 2. Bilateral c-shaped canals

Table 2. Frequency of distal root canal configuration types

Distal root type	Tooth side		
	Left	Right	Total
Type Ⅰ	150 (96.8%)	137 (99.3%)	287 (98.0%)
Type Ⅱ	1 (.6)%	0 (.0%)	1 (.3%)
Type Ⅴ	4 (2.6%)	1 (.7%)	5 (1.7%)
Total	155 (100.0%)	138 (100.0%)	293 (100.0%)

more complex anatomy. One case displayed a 2-1-2-1 canal pattern (1.1%). The remaining cases (25.3%) had different anatomical configurations between the right and left sides (Table 3). Notably, type VII and type VIII canals were absent in right second molars, while left second molars lacked types VI, VII, and VIII (p = 0.999).

2. Gender

In this context, cases were evaluated that featured second molars on both sides of the mandible. In both genders, most cases exhibited two roots in the second molars on both sides (male: 62.7%, female: 80.9%). This was followed by C-shaped canals in males (7.8%) and second molars with two roots on the right side and one root on the left side in females (6.1%). The distribution of different root canal shapes in the second molars on both sides of the mandible was compared using the exact Chi-square test. The results indicated no significant difference in the root canal shapes of second molars between males and females (p= 0.502).

Both genders had a distal root with one canal on each side of the mandible (91.1% in males and 100% in females) (p= 0.502). However, different types of canals were observed in the mesial root, with type III being the most common (male: 37.8%, female: 28.3%). Additionally, significant differences were noted in the mesial canals on the right and left sides (p= 0.933) (Table 4).

3. Age

Most individuals over the age of 50 had second molars on both sides of the mandible with two roots (80%). This age group also exhibited the highest prevalence of C-shaped roots, at 13.3%. In the 36-50 age group, all second molars on both sides of the mandible displayed a type I distal root (100%). Meanwhile, in the group under 20 years old, type III anatomy of the mesial canals was the most prevalent, occurring in 50% of cases. Overall, this anatomical variation accounted for 33% of cases across all age groups (Table 5). This revision improves clarity and provides a smoother reading experience while retaining all key information.

Table 3. Frequency of mesial root canal configuration types

Root shape	Tooth side (number/percentage)		Total
	Left	Right	
Type Ⅰ	37(23.9%)	22(15.9%)	59(20.1%)
Type Ⅱ	19(12.3%)	16(11.6%)	35(11.9%)
TypeⅢ	61(39.4%)	58(42.0%)	119(40.6%)
TypeⅣ	11(7.1%)	14(10.1%)	25(8.5%)
Type Ⅴ	23(14.8%)	20(14.5%)	43(14.7%)
TypeⅥ	2(1.3%)	5(3.6%)	7(2.4%)
New1	0(.0%)	1(.7%)	1(.3%)
New2	2(1.3%)	2(1.4%)	4(1.4%)
Total	**155 (100.0%)**	**138 (100.0%)**	**293 (100.0%)**

Table 4. Comparison of the Distribution of Root Numbers Between Women and Men

Root shape	Gender		Total
	Male	Female	
Right side 2 roots Left side 2 roots	32(62.7%)	38(80.9%)	70(71.4%)
Right side 2 roots Left side 3 roots	3(5.9%)	0(.0%)	3(3.1%)
Right side 2 roots Left side 2-1 root	2(3.9%)	3(6.4%)	5(5.1%)
Right side 3 roots Left side 2 roots	2(3.9%)	1(2.1%)	3(3.1%)
Right side 4 roots Left side 2 roots	1(2.0%)	0(.0%)	1(1.0%)
Right side 4 roots Left side 4 roots	1(2.0%)	0(.0%)	1(1.0%)
Left side 2 roots Right side 2-1 roots	2(3.9%)	2(4.3%)	4(4.1%)
left side 2-1 roots Right side 2-1 roots	2(3.9%)	2(4.3%)	4(4.1%)
Right side C-shaped Left side 2 roots	1(2.0%)	0(.0%)	1(1.0%)
Right side C-shaped Left side C-shaped	4(7.8%)	1(2.1%)	5(5.1%)
Right side 1-2-1 root Left side 1 roots	1(2.0%)	0(.0%)	1(1.0%)
Total	**51(100.0%)**	**47(100.0%)**	**98(100.0%)**

Table 5. Frequency distribution of root numbers across different age groups

Root shape	Age				Total
	More than 50	35-60	20-35	Less than 20	
Right side 2 roots Left side 2 roots	12(80.0%)	30(76.9%)	24(64.9%)	4(57.1%)	70(71.4%)
Right side 2 roots Right side 3 roots	0(0%)	0(0%)	2(5.4%)	1(14.3%)	3(3.1%)
Right side 2 roots left side 2-1 roots	0(.0%)	2(5.1%)	3(8.1%)	0(.0%)	5(5.1%)
Right side 3 roots Left side 2 roots	0(.0%)	1(2.6%)	2(5.4%)	0(.0%)	3(3.1%)
Right side 4 roots Left side 2 roots	1(6.7%)	0(.0%)	0(.0%)	0(.0%)	1(1.0%)
Right side 4 roots Left side 4 roots	0(.0%)	0(.0%)	0(.0%)	1(14.3%)	1(1.0%)
Right side 2-1 roots Left side 2 roots	0(.0%)	0(.0%)	4(10.8%)	0(.0%)	4(4.1%)
Right side 2-1 roots Left side 2-1 roots	0(.0%)	3(7.7%)	1(2.7%)	0(.0%)	4(4.1%)
Right side C-shaped Left side 2 roots	0(.0%)	1(2.7%)	0(.0%)	0(.0%)	1(1.0%)
Right side C-shaped Left side C-shaped	2(13.3%)	2(5.1%)	1(2.7%)	0(.0%)	5(5.1%)
Right side 1-2-1 Left side 1 root	0(.0%)	0(.0%)	0(.0%)	1(14.3%)	1(1.0%)
Total	**15(100.0%)**	**39(100.0%)**	**37(100.0%)**	**98(100.0%)**	**98(100.0%)**

Discussion

This study evaluated the root canal morphology of mandibular second molars in an Iranian population using CBCT. The findings revealed that the most common morphology encompassed two roots (81.5%), followed by 2-1 root morphology (7.2%) (Table 1). These results align with certain previous studies (5, 16, 17) but also highlight unique characteristics specific to the Iranian population. Additionally, some mandibular second molars exhibited three roots (2.2%), consistent with similar findings among Caucasians (1.8%–2.7%) (18), though differing from studies in Eskimos, North Americans, Indians, and Koreans, which reported higher percentages (25.3%–51.4%) of a third root (19).

In this study, Vertucci's classification system was employed to categorize canal configurations (13). The prevalence of Type I canal configurations in the distal root was comparable to other studies (Table 2) (20-22). However, in mesial canals, Type III was most common in our sample population, contrasting with Buchanan et al. (17), who found Type IV to be the most prevalent in a South African population. Similar Type IV dominance in mesial canals was observed in studies on Croatian (11), Gansu (23), Turkish (24), and Egyptian (25) populations. Conversely, in the United Arab Emirates, Type II and Type III were most common in mesial roots (26), while among Venezuelans, Type II followed by Type IV were predominant (16). These variations emphasize the need for regional studies to better understand population-specific root canal morphologies, suggesting potential genetic or environmental influences in the Iranian population.

The prevalence of C-shaped canals in this study was 5.1% (Table 1), which is similar to Turkish populations (4.1%) (24) but lower than that found in Belgians (10.7%) (27), Saudis (9.1%) (28), Yemenis (9%) (21), Chileans (8.9%) (27), and Brazilians (8.5%) (29). However, the prevalence of C-shaped canals was notably higher in Chinese (29%–47.05%) (30-32), Koreans (44.5%) (33), and Malaysians (48.7%) (34), potentially due to racial and ethnic differences (17). Previous Iranian studies reported a higher prevalence of C-shaped canals (17.6%, 21.4%)in Iranian samples (20, 35), possibly due to differences in sample size, imaging parameters, or geographic focus.

Regarding gender, this study found a higher prevalence of C-shaped canals in males (7.4%) (Table 4), in agreement with Martins et al. (18), though other studies reported higher prevalence among females (23, 25). Some studies observed no significant gender difference in C-shaped canal prevalence (16, 17, 36, 37). Additionally, one study noted that C-shaped canals and extra roots are more frequent in younger individuals (11), while another found that pulp chamber height and the number of root canals decline with age (23). However, other studies reported no age-related differences in root canal anatomy for mandibular second molars (17, 36). In our study, the highest prevalence of C-shaped canals was found in individuals over 50 (13.3%), while the highest variation in mesial canal types (Type III, 50%) was observed in those under 20 (Table 5). These findings suggest that age-related changes in the dentine-pulp complex, such as secondary dentin formation, may impact endodontic outcomes by complicating canal structure.

Understanding the prevalence of root canal configurations in the Iranian population can improve the accuracy of endodontic treatments, allowing clinicians to anticipate specific canal types and thereby enhance treatment success. However, missed canals due to incomplete biofilm removal can lead to post-treatment apical periodontitis, contributing to ongoing or new infections (38). CBCT imaging aids in accurate canal morphology identification, though its resolution may not capture intricate canal complexities (39). While high-resolution imaging is ideal in endodontics, CBCT use is limited by radiation exposure concerns and potential artifacts from metallic restorations, which can obscure root canal anatomy and pathologies like root resorption or fractures (12).

This study's sample, though representative, may not fully reflect the diversity of the Iranian population, as participants were drawn from Tehran, a city with a range of ethnicities that may not generalize to all regions. Although CBCT has clear advantages, its resolution remains inferior to micro-CT, a method often used in anatomical studies of root canal morphology due to its capacity to capture fine details. However, micro-CT's use is

restricted to non-living subjects due to high radiation exposure and significant cost (17, 40). Thus, many epidemiological studies rely on CBCT for ethical and practical reasons, typically only including patients already requiring CBCT for clinical purposes (11).

Future research should expand sample sizes to better represent the Iranian population and explore other imaging techniques like micro-CT for enhanced detail. Examining genetic and environmental factors that influence canal morphology could also provide valuable insights into root canal anatomy, enhancing endodontic treatment strategies for specific populations.

Conclusion

In the studied Iranian population, mandibular second molars predominantly had two roots. The most common canal configurations were Type I in the distal root and Type III in the mesial root. The prevalence of C-shaped canals was low, and root morphology did not differ between sides of the mandible or between genders.

Declarations

1. Ethical approval

This *in vivo* investigation received approval from the Research Ethics Committee of Shahed University (IR.SHDU.Dent.Res. 1397070) and was conducted using available human CBCT images involving mandibular second molar teeth.

2. Availability of data and materials

The data supporting the findings of this investigation will be available upon request from the corresponding author [MP].

3. Competing interests

The authors of the manuscript affirm that they have not received any financial support by any producing company pertaining to the study and therefore they have no conflicts of interest to declare pertaining to this work.

4. Funding

This research was conducted as part of an undergraduate dissertation and did not receive any external funding.

5. Author contribution

The study was conceptualized and designed by H.A., who also developed the methodology, managed software requirements, and led the validation, formal analysis, and investigation phases. H.A. further contributed through manuscript review and editing, enhancing clarity and coherence, and oversaw data visualization. Additionally, H.A. provided overall supervision and managed project administration, ensuring alignment with study objectives, adherence to the timeline, and successful execution of each project phase. A.H. was instrumental in securing necessary resources and curated the data for analysis. M.P. drafted the original manuscript, structured the initial narrative, and ensured that findings were communicated clearly and effectively.

Acknowledgements

The authors would like to express their gratitude to Dr. Sara Jambarsang for her cooperation in performing the statistical tests. In addition, authors would like to thank Dr. Shahriar Shahab for his assistance in providing CBCT images.

References

1. Mimica S, Simeon P, Miletić I, Baraba A, Jukić Krmek S. Cone-Beam Computed Tomography Analysis of the Root Canal Morphology of Lower Second Molars in the Croatian Subpopulation. Applied Sciences. 2024;14(2).

2. Liu H, Shen Y. Endodontic Treatment of a Mandibular Second Molar Featuring Vertucci Type V Configuration in the Distal Root: A Case Report. Cureus. 2024;16(5): e59905.

3. Buchanan GD, Gamieldien MY, Fabris-Rotelli I, van Schoor A, Uys A. Investigation of mandibular second molar root and canal morphology in a Black South African population using cone-beam computed tomography and two classification systems. J Oral Sci. 2023;65(4):226-31.

4. Senan E, Alhadainy H, Madfa AA. Root and Canal Morphology of Mandibular Second Molars in a Yemeni Population: A Cone-beam Computed Tomography. Eur Endod J. 2021;6(1):72-81.

5. Karkhaneh M, Karkehabadi H, Alafchi B, Shokri A. Association of root morphology of mandibular second molars on panoramic-like and axial views of

cone-beam computed tomography. BMC Oral Health. 2023; 23(1):856.
6. Saber SM, Seoud MAE, Sadat S, Nawar NN. Root and canal morphology of mandibular second molars in an Egyptian subpopulation: a cone-beam computed tomography study. BMC Oral Health. 2023;23(1):217.
7. Pawar AM, Pawar M, Kfir A, Singh S, Salve P, Thakur B, et al. Root canal morphology and variations in mandibular second molar teeth of an Indian population: an in vivo cone-beam computed tomography analysis. Clin Oral Investig. 2017; 21 (9):2801-9.
8. Shaikh S, Patil AG, Kalgutkar VU, Bhandarkar SA, Hakke Patil A. The Assessment of C-shaped Canal Prevalence in Mandibular Second Molars Using Endodontic Microscopy and Cone Beam Computed Tomography: An In Vivo Investigation. Cureus. 2024; 16(6):e62026.
9. Gomez F, Brea G, Gomez-Sosa JF. Root canal morphology and variations in mandibular second molars: an in vivo cone-beam computed tomography analysis. BMC Oral Health. 2021;21(1):424.
10. Guo Q, Wang Q, Yang Y, Guo D. Root and root canal morphology of mandibular second permanent molars in the Gansu province population: A CBCT study. Aust Endod J. 2023;49 Suppl 1:27-32.
11. Mimica S, Simeon P, Miletić I, Baraba A, Jukić Krmek S. Cone-Beam Computed TomographyAnalysis of the Root Canal Morphology of Lower Second Molars in the Croatian Subpopulation. Applied Sciences. 2024;14(2):871.
12. Wolf TG, Paqué F, Betz P, Willershausen B, Briseño-Marroquín B. Micro-CT assessment of internal morphology and root canal configuration of non C-shaped mandibular second molars. Swiss Dental Journal. 2017; 127(6):513-9.
13. Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. Endodontic topics. 2005; 10(1): 3-29.
14. Melton DC, Krell KV, Fuller MW. Anatomical and histological features of C-shaped canals in mandibular second molars. Journal of endodontics. 1991; 17(8):384-8.
15. Wang Y, Guo J, Yang H-B, Han X, Yu Y. Incidence of C-shaped root canal systems in mandibular second molars in the native Chinese population by analysis of clinical methods. International Journal of Oral Science. 2012;4(3):161-5.
16. Gomez F, Brea G, Gomez-Sosa JF. Root canal morphology and variations in mandibular second molars: an in vivo cone-beam computed tomography analysis. BMC Oral Health. 2021;21:1-7.
17. Buchanan GD, Gamieldien MY, Fabris-Rotelli I, van Schoor A, Uys A. Investigation of mandibular second molar root and canal morphology in a Black South African population using cone-beam computed tomography and two classification systems. Journal of Oral Science. 2023;65(4):226-31.
18. Martins JN, Marques D, Mata A, Caramês J. Root and root canal morphology of the permanent dentition in a Caucasian population: a cone-beam computed tomography study. International endodontic journal. 2017;50(11): 1013-26.
19. Kantilieraki E, Delantoni A, Angelopoulos C, Beltes P. Evaluation of root and root canal morphology of mandibular first and second molars in a Greek population: a CBCT study. Eur Endod J. 2019; 4 (2):62-8.
20. Janani M, Rahimi S, Jafari F, Johari M, Nikniaz S, Ghasemi N. Anatomic features of C-shaped mandibular second molars in a selected Iranian population using CBCT. Iranian Endodontic Journal. 2018; 13(1):120.
21. Senan E, Alhadainy H, Madfa AA. Root and canal morphology of mandibular second molars in a Yemeni population: a cone-beam computed tomography. European endodontic journal. 2021; 6(1):72.
22. Sharaan ME, Elrawdy AM. An evaluation of mandibular molars root canal morphology using cone-beam computed tomography in an Egyptian subpopulation. Tanta Dental Journal. 2017; 14(4):220-4.
23. Guo Q, Wang Q, Yang Y, Guo D. Root and root canal morphology of mandibular second permanent molars in the Gansu province population: A CBCT study. Australian Endodontic Journal. 2023; 49:27-32.
24. Demirbuga S, Sekerci AE, Dinçer AN, Cayabatmaz M, Zorba YO. Use of cone-beam computed tomography to evaluate root and canal morphology of mandibular first and second molars in Turkish individuals. Medicina oral, patologia oral y cirugia bucal. 2013;18(4):e737.
25. Saber SM, Seoud MaE, Sadat SMAe, Nawar NN. Root and canal morphology of mandibular second molars in an Egyptian subpopulation: a cone-beam computed tomography study. BMC Oral Health. 2023; 23(1):217.
26. Khawaja S, Alharbi N, Chaudhry J, Khamis AH, Abed RE, Ghoneima A, et al. The C-shaped root canal systems in mandibular second molars in an Emirati population. Scientific reports. 2021;11(1):23863.
27. Torres A, Jacobs R, Lambrechts P, Brizuela C, Cabrera C, Concha G, et al. Characterization of mandibular molar root and canal morphology using cone beam computed tomography and its variability in Belgian and Chilean

population samples. Imaging science in dentistry. 2015; 45(2):95-101.
28. Alfawaz H, Alqedairi A, Alkhayyal AK, Almobarak AA, Alhusain MF, Martins JN. Prevalence of C-shaped canal system in mandibular first and second molars in a Saudi population assessed via cone beam computed tomography: a retrospective study. Clinical Oral Investigations. 2019; 23:107-12.
29. Nejaim Y, Gomes AF, Rosado LdPL, Freitas DQ, Martins JN, da Silva EJNL. C-shaped canals in mandibular molars of a Brazilian subpopulation: prevalence and root canal configuration using cone-beam computed tomography. Clinical Oral Investigations. 2020;24:3299-305.
30. Chen C, Zhu T, Wu H, Zhao X, Leng D, Wang J, et al. Prevalence and correlation of C-shaped root canals of mandibular premolars and molars in Eastern Chinese individuals. Scientific Reports. 2022; 12(1): 19779.
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. International Endodontic Journal. 2011;44 (11):990-9.
32. Zheng Q, Zhang L, Zhou X, Wang Q, Wang Y, TangL, et al. C-shaped root canal system in mandibular second molars in a Chinese population evaluated by cone-beam computed tomography. International Endodontic Journal. 2011;44(9):857-62.
33. Kim H-S, Jung D, Lee H, Han Y-S, Oh S, Sim H-Y. C-shaped root canals of mandibular second molars in a Korean population: a CBCT analysis. Restorative Dentistry & Endodontics. 2018;43(4).
34. Pan JYY, Parolia A, Chuah SR, Bhatia S, Mutalik S, Pau A. Root canal morphology of permanent teeth in a Malaysian subpopulation using cone-beam computed tomography. BMC oral health. 2019;19:1-15.
35. Madani ZS, Mehraban N, Moudi E, Bijani A. Root and canal morphology of mandibular molars in a selected Iranian population using cone-beam computed tomography. Iranian Endodontic Journal. 2017; 12(2): 143.
36. Alazemi HS, Al-Nazhan SA, Aldosimani MA. Root and root canal morphology of permanent mandibular first and second molars in a Kuwaiti population: A retrospective cone-beam computed tomography study. The Saudi Dental Journal. 2023; 35 (4):345-53.
37. Shaikh S, Patil AG, Kalgutkar VU, Bhandarkar SA, Patil AH. The Assessment of C-shaped Canal Prevalence in Mandibular Second Molars Using Endodontic Microscopy and Cone Beam Computed Tomography: An In Vivo Investigation. Cureus. 2024; 16(6):e62026.
38. Hao J, Liu H, Shen Y. Periapical lesions and missed canals in endodontically treated teeth: a cone-beam computed tomographic study of a Chinese subpopulation. Medical Science Monitor: International Medical Journal of Experimental and Clinical Research. 2023;29:e940533-1.
39. Ordinola-Zapata R, Bramante CM, Versiani MA, Moldauer BI, Topham G, Gutmann J, et al. Comparative accuracy of the Clearing Technique, CBCT and Micro-CT methods in studying the mesial root canal configuration of mandibular first molars. International Endodontic Journal. 2017; 50(1):90-6.
40. Alak SG, Keleş A, Keskin C, Martins JN, Versiani MA. Age-related changes in the morphology of the root canal system of mandibular first molars: a micro-CT study. Clinical Oral Investigations. 2023; 27(8):4667-75.