BJHS
Birat Journal of Health Sciences

ISSN:

2542-2758 (Print) 2542-2804 (Online)

ARTICAE INFO:

Received Date: 4 September, 2024
Accepted Date: 16 December, 2024
Published Date: 30 April, 2025

KEYWORDS:

Canal; cone-beam computed tomography; molar; prevalence; root.

CORRESPONDING AUTHOR:

Md. Asdaq Hussain
Lecturer, Department of Conservative Dentistry & Endodontics National Medical College, Birgunj, Nepal
Email: drasdaq9291@gmail.com
ORCID: 0000-0001-9293-9194

Access the article online

DOI: 10.62065/bjhs603

CITATION:

Hussain MA, Acharya N, Chakradhar A, Naz S, Zahra A, Khatoon S. C-shaped Canals in Mandibular Second Molars: A Cone Beam Computed Tomography Analysis. 2025; 9 (2): 25-30.

C-shaped Canals in Mandibular Second Molars: A Cone Beam Computed Tomography Analysis

Md. Asdaq Hussain[1], Nisha Acharya[2], Anil Chakradhar[3], Shazia Naz[4], Ambreen Zahra[5], Samina Khatoon[6]

[1] Lecturer, Department of Conservative Dentistry & Endodontics, National Medical College, Birgunj, Nepal
[2] Assistant Professor, Department of Conservative Dentistry and Endodontics, Institute of Medicine (IOM), Maharajgunj Medical Campus, Tribhuvan University Teaching Hospital (TUTH), Maharajgunj, Kathmandu, Nepal
[3] Lecturer, Department of Conservative Dentistry and Endodontics, Kathmandu University School of Medical Sciences, Dhulikhel, Kavrepalanchok, Nepal
[4] Associate Professor, Department of Operative Dentistry, de'Montmorency College of Dentistry, Lahore, Pakistan
[5] Demonstrator, Department of Operative Dentistry, Avicenna Dental College, Lahore, Pakistan
[6] Dental Surgeon, Department of Conservative Dentistry & Endodontics, National Medical College, Birgunj, Nepal

ABSTRACT

Introduction: A thorough grasp of possible anatomical variations is crucial for successful root canal treatment. An example of such a variation is the C-shaped canal morphology, primarily observed in mandibular second molars. This morphology is distinguished by a cross-sectional configuration resembling the letter "C."

Objective: This study aimed to assess the prevalence of C-shaped canals in permanent mandibular second molars among patients attending a tertiary care hospital in Nepal, utilizing cone-beam computed tomography (CBCT).

Methodology: This descriptive cross-sectional study was conducted at the Department of Conservative Dentistry and Endodontics, Kathmandu University School of Medical Sciences (KUSMS)- Dhulikhel Hospital, Nepal, from December 2020 to November 2021. Ethical approval was obtained from the Institutional Review Committee of KUSMS prior to the study. CBCT scans of 150 mandibular second molars were evaluated by two endodontists. The study assessed tooth position (right or left side), prevalence of C-shaped canals, classification of C-shaped canal configurations at the orifice cross-sectional level, and the occurrence of C-shaped canals unilaterally or bilaterally. Data were analyzed using SPSS.

Results: Out of the 150 teeth examined, 13 (8.7%) teeth exhibited a C-shaped root canal system. Among these 13 teeth, 7 (53.8%) teeth had an uninterrupted "C" configuration at the orifice level.

Conclusions: This study found a notable prevalence of C-shaped root canals in mandibular second molars among the Nepalese population sampled.

INTRODUCTION

A thorough grasp of possible anatomical variations is crucial for the successful completion of root canal treatment.[1] An example of such a variation is the existence of C-shaped canal morphology, distinguished by a cross-sectional configuration resembling the letter "C" within the root canal. Its primary

anatomical feature includes the occurrence of fins or isthmuses linking individual root canals, with the orifice possibly appearing as a single ribbon-shaped opening spanning an arc of 180° or more, resulting in variable cross-sectional and three-dimensional shapes throughout the root.[2] Predictably, this morphological complexity poses significant challenges in terms of debridement, disinfection, and canal filling techniques, all of which can eventually impact the prognosis of endodontic treatment.[3]

Studies have reported the prevalence of C-shaped root canals ranging from 2.7% to 8%.[4,5] This anatomical feature shows notable ethnic variation with a higher frequency among individuals of Asian descent.[6] Recent meta-analysis has suggested that both geographic region and gender could potentially serve as confounding variables impacting the C-shaped prevalence in mandibular second molars.[7]

Cone-beam computed tomography (CBCT) has become an invaluable technique for exploring anatomy of root canal. Its three-dimensional images offer a more accurate and comprehensive knowledge of the root canal morphology compared to conventional two-dimensional radiography.[8,9] Additionally, CBCT's noninvasive nature enables studies to include increased sample sizes compared to those employing microscopic examination.[9,10]

Given these advancements, the association of detailed anatomical knowledge with a sophisticated diagnostic tool like CBCT can significantly aid clinicians in anticipating and managing complex root canal configurations in practice. This will provide valuable insights into the anatomical variations present in this population and enhance the effectiveness of endodontic treatments. Therefore, this study aimed to assess the prevalence of C-shaped root canals in permanent mandibular second molars among individuals attending a tertiary care hospital in Nepal, utilizing CBCT.

METHODOLOGY

This descriptive cross-sectional study was conducted at the Department of Conservative Dentistry and Endodontics, Kathmandu University School of Medical Sciences (KUSMS) - Dhulikhel Hospital, Nepal, spanning from December 2020 to November 2021. The Institutional Review Committee (IRC) of Kathmandu University School of Medical Sciences (KUSMS) approved this study under protocol number 113/20.

Patients undergoing dental examination, diagnosis, and treatment planning that required CBCT imaging for orthodontics, trauma, implants, temporomandibular joint disorders, and other purposes were included. Informed consent was acquired from all participants included in the study. The inclusion/exclusion criteria of the study were as follows:

Inclusion criteria:

- Nepalese patients aged 18 years and older
- Availability of CBCT images showing at a minimum one fully erupted permanent mandibular second molar with completely formed roots
- Absence of previous root canal treatment, posts or crowns

Exclusion criteria:

- Teeth with open apices, root resorption, root anomalies, or calcified canals
- Presence of extensive coronal and root caries, periapical lesions or root fracture
- Unclear or distorted CBCT images

A convenience sampling method was employed to gather the sample. The sample size was calculated utilizing a standard formula, taking into account 85% power at a 95% confidence interval (CI). $n = \frac{Z^2 P(1-P)}{d^2}$

Based on a previous study, the final sample size was 150 teeth, with each mandibular second molar counted as a separate sample.[11]

Image acquisition

The CBCT scans were obtained utilizing the RainbowTM CT device (Dentium, South Korea), which operated at a peak voltage of 100kV and tube current of 12mA, with a field of view measuring 16 cm x 18 cm, voxel size set at 300 µm, and a scan duration of 20 seconds. A well-trained radiologist conducted all image acquisitions.

Image evaluation

The RainbowTM image viewer software program, version 1.0.0.0 (Dentium, South Korea), was utilized to reconstruct the cross-sectional images. These images were then assessed on a Dell E1912H 19" monitor (Dell, Texas, United States) with a resolution of 1280 × 1024 and 64-bit color depth, using an HD Graphics card from Intel (California, United States).

The evaluation of the CBCT scans was carried out by two endodontists (MAH and NA), who underwent calibration at the outset of the study. This calibration involved assessing 20 random cases of lower second molars for the presence of C-shaped canals, with a two-week gap between examinations. The reliability of their assessments was analyzed using the Cohen's Kappa Coefficient (κ). The κ value for inter-examiner agreement was 0.77 indicating substantial agreement.

The following data were documented for mandibular second molars:

- Tooth position (right or left side).
- Prevalence of C-shaped canals, which were identified according to criteria outlined by Fan et al., which included the presence of fused roots, a longitudinal groove on the lingual, buccal or both surfaces of the root, and at least one cross-section of the canal falling into the C1, C2, or C3 configuration.2
- Classification of C-shaped canal configurations at the orifice cross-sectional level.
- Occurrence of C-shaped canals unilaterally or bilaterally.

The canal configurations were classified at the orifice cross-sectional level as follows, based on Fan et al.:

Category I (C1): The shape displayed a continuous "C" without any separation or division.

Category II (C2): The canal shape resembled a semicolon due to a discontinuation in the "C" outline, typically occurring when the angle is greater than or equal to 60 degrees.

Category III (C3): Two or three canals were separated along the axis of the C-shaped configuration, commonly observed when the angle is less than 60 degrees.

Category IV (C4): A singular round or oval canal was visible in that cross-section.
Category V (C5): No canal lumen was visible.
Data were entered in a Microsoft Excel 2010 and analyzed using descriptive statistical methods, including frequency, percentage, and mean with SPSS (Statistical Package for the Social Sciences) version 16 for Windows.

RESULTS

A total of 150 mandibular second molars were assessed, with 46% from male patients and 54% from female patients. The patients' ages varied between 18 and 73 years, with a mean age of 33.31 years. Concerning tooth position, 51.3% were located on the mandibular right side, and 48.7% were on the mandibular left side.
Among the 150 mandibular second molars examined, the prevalence of C-shaped root canals was 8.7% i.e., 13 teeth. (Table 1). The prevalence of C-shaped canals was higher in females (14.8%) than in males (1.4%).

Table 1. Prevalence of C-shaped canals in mandibular second molars by gender and side

Variable	Present (No., %)	Absent (No., %)	Total (No., %)
Gender			
Male	1 (1.4)	68 (98.6)	69 (100.0)
Female	12 (14.8)	69 (85.2)	81 (100.0)
Side			
Right	7 (9.1)	70 (90.9)	77 (100.0)
Left	6 (8.2)	67 (91.8)	73 (100.0)
Total	13 (8.7)	137 (91.3)	150 (100.0)

The predominant canal configuration observed among C-shaped canal orifices was Category I (C1), accounting for 53.8%, followed by Category II (C2) at 38.5%, and Category III (C3) at 7.7% (Table 2).

Table 2. Canal configurations at orifice cross-sectional level of C-shaped root canals in mandibular second molars by gender and side

Configuration	C1 canal No. (%)	C2 canal No. (%)	C3 canal No. (%)
Gender			
Male	0 (0.0)	1 (100.0)	0 (0.0)
Female	7 (58.3)	4 (33.3)	1 (8.3)
Side			
Right	3 (42.9)	4 (57.1)	0 (0.0)
Left	4 (66.6)	1 (16.7)	1 (16.7)
Total	7 (53.8)	5 (38.5)	1 (7.7)

Abbreviations: C1, Category 1; C2, Category 2; C3, Category 3
In 76.9% of cases (10 out of 13 C-shaped canals), the prevalence of bilateral occurrence was noted. Among females, the majority (71.4%) of C-shaped canals were observed bilaterally (Table 3).

Table 3. Prevalence of unilateral and bilateral C-shaped canals by gender

Gender	Unilateral (No., %)	Bilateral (No., %)	Total (No., %)
Male	1 (100.0)	0 (0.0)	1 (100.0)
Female	2 (28.6)	5 (71.4)	7 (100.0)
Total	3 (37.5)	5 (62.5)	8 (100.0)

DISCUSSION

Achieving successful endodontic therapy demands a thorough understanding of the anatomical intricacies of the root and root canal system. Lack of knowledge and failure to identify all root canals are cited as the primary reasons for failure in endodontic treatment failure.[12] This study aimed to bridge the gap in understanding of C-shaped canal morphology in mandibular second molars among patients treated at a tertiary care facility in Nepal, using CBCT.
Researchers globally have explored the root canal anatomy of mandibular second molars using a variety of techniques.[2,4,6,8,9,13] CBCT stands out as a nondestructive, noninvasive imaging modality capable of detecting most of anatomical variations and providing a precise depiction of both internal and external dental anatomy. It offers the advantage of low radiation exposure and comprehensive imaging, making it a safe and effective tool for visualizing morphology of root canal prior to treatment.[14]

In the current study, two endodontists assessed the root canal anatomy of the lower second molar, enhancing the study's reliability. A comparable approach for image assessment was employed, as seen in a study conducted by Senan et al.[15] In this study, Fan et al.'s classification, which is a modified version of Melton's method, was utilized to categorize the C-shaped configuration.[16] Fan et al.'s criteria offer more comprehensive definitions compared to Melton's system and have consequently been utilized in the majority of recent studies.[8,10,15,17,18]

Our results show a prevalence of 8.7% for C-shaped canals in mandibular second molars. Comparable percentages were reported in Indian (9.7%), Yemeni (9%), Turkish (8.9%), Saudi (9.1%), and Sudanese (10%) population.[11,15,19,20,21] This 8.7% prevalence agrees a previous study carried out in Nepalese subpopulation.[22] However, notably different results were observed in Chinese (38.6%) and Korean (40%) population.[8,10] This difference may be ascribed to dissimilarities in race, sample sizes, methodologies and analysis techniques.

In this research, a higher prevalence of C-shaped canals was observed in females compared to males. This finding aligns with research conducted among Korean, Saudi, and Iraqi populations.[10,20,23] Conversely, no significant gender-based variations were detected in Chinese, Indian, Turkish and Egyptian cohorts.[8,11,19,24] These differences highlight the ongoing disparities within and between ethnic groups. Our study found similar prevalence of C-shaped canals in both left and right mandibular second molars. This finding is in agreement with those reported in previous studies.[8,10,19,25]

Fan et al. utilized micro-computed tomography to inspect the C-shaped canals and found that most cases displayed an

uninterrupted "C" pattern.2 In our study, the most prevalent configuration was C1 (53.8%), which contradicts some previous research2 suggesting C2 as predominant at the orifice level.[23,26] These discrepancies may be due to variations in the sample sources and methodological approaches.

Our findings also support the observation that C-shaped canals are often bilateral. Sabala et al. documented that when a C-shaped canal is identified on one side, it can be found in the contralateral side in more than 70% of cases.[27] Similarly, our study found that 77% of C-shaped canals were bilateral, which has significant clinical implications for endodontic therapy.

This research adds to the limited understanding of C-shaped canals in the Nepalese population. Previous studies indicate that molars with fused roots that have undergone root canal treatment are more likely to develop apical lesions than non-fused teeth.[28] Therefore, using CBCT for identifying root and canal morphology is clinically valuable, particularly when conventional radiographs may be insufficient.

CONCLUSION

This study found a notable prevalence of C-shaped root canals in mandibular second molars among the sampled Nepalese population, with an 8.7% occurrence rate. The findings highlight the importance of incorporating advanced imaging techniques, such as CBCT, in endodontic practice to accurately diagnose and manage these complex canal systems. The higher prevalence observed in females and the significant rate of bilateral occurrences underscore the need for careful examination of both molars in clinical settings.

RECOMMENDATIONS

To enhance the generalizability of these findings, further research involving a broader, multi-centric sample across various age groups and geographic regions is recommended. Additionally, future studies should explore the relationship between canal morphology and treatment outcomes to refine endodontic strategies for managing C-shaped canals.

LIMITATIONS OF THE STUDY

This study has some limitations. Conducted at a single facility, it may not fully represent the broader Nepalese population. Additionally, the average age of participants was 33.31 years, which could impact the generalizability of the findings. A multicenter study with a more diverse age range is recommended to enhance the applicability of the results. Furthermore, while the study assessed canal shape at the orifice level, C-shaped canals can vary along the root length, which may not be fully captured by this approach.

ACKNOWLEDGEMENTS: We acknowledge all the participants for their valuable time and cooperation.

CONFLICT OF INTEREST: None

FINANCIAL DISCLOSURE: None

REFERENCES

1. Vertucci F. Root canal morphology and its relationship to endodontic procedures. Endod Topics. 2005 Aug;10:3-29. DOI: 10.1111/j.1601-1546.2005.00129

2. Fan B, Cheung GS, Fan M, Gutmann JL, Bian Z. C-shaped canal system in mandibular second molars: Part I--Anatomical features. J Endod. 2004 Dec;30(12):899-903. DOI: 10.1097/01.don.0000136207.12204.e4 PMID: 15564874

3. Amoroso-Silva PA, Ordinola-Zapata R, Duarte MA, Gutmann JL, del Carpio-Perochena A, Bramante CM, de Moraes IG. Micro-computed Tomographic Analysis of Mandibular Second Molars with C-shaped Root Canals. J Endod. 2015 Jun;41(6):890-5. DOI: 10.1016/j.joen.2015.01.021 PMID: 25732399

4. Weine FS, Pasiewicz RA, Rice RT. Canal configuration of the mandibular second molar using a clinically oriented in vitro method. J Endod. 1988 May;14(5):207-13. DOI: 10.1016/S0099-2399(88)80171-7 PMID: 3251974

5. Cooke HG 3rd, Cox FL. C-shaped canal configurations in mandibular molars. J Am Dent Assoc. 1979 Nov;99(5):836-9. DOI: 10.14219/jada.archive.1979.0402 PMID: 290680

6. Seo MS, Park DS. C-shaped root canals of mandibular second molars in a Korean population: clinical observation and in vitro analysis. Int Endod J. 2004 Feb;37(2):139-44. DOI: 10.1111/j.0143-2885.2004.00772.x PMID: 14871181

7. 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 Nov;52(11):1556-72. DOI: 10.1111/iej.13169 PMID: 31215045

8. Zheng Q, Zhang L, Zhou X, Wang Q, Wang Y, Tang L, Song F, Huang D. C-shaped root canal system in mandibular second molars in a Chinese population evaluated by cone-beam computed tomography. Int Endod J. 2011 Sep;44(9):857-62. DOI: 10.1111/j.1365-2591.2011.01896.x PMID: 21599707

9. Neelakantan P, Subbarao C, Subbarao CV, Ravindranath M. Root and canal morphology of mandibular second molars in an Indian population. J Endod. 2010 Aug;36(8):1319-22. DOI: 10.1016/j.joen.2010.04.001 PMID: 20647088

10. Kim SY, Kim BS, Kim Y. Mandibular second molar root canal morphology and variants in a Korean subpopulation. Int Endod J. 2016 Feb;49(2):136-44. DOI: 10.1111/iej.12437 PMID: 25652228

11. Wadhwani S, Singh MP, Agarwal M, Somasundaram P, Rawtiya M, Wadhwani PK. Prevalence of C-shaped canals in mandibular second and third molars in a central India population: A cone beam computed tomography analysis. J Conserv Dent. 2017 Sep-Oct;20(5):351-4.
DOI: 10.4103/JCD.JCD_273_16
PMID: 29386785 PMCID: PMC5767832

12. Kim Y, Lee SJ, Woo J. Morphology of maxillary first and second molars analyzed by cone-beam computed tomography in a Korean population: variations in the number of roots and canals and the incidence of fusion. J Endod. 2012 Aug;38(8):1063-8.
DOI: 10.1016/j.joen.2012.04.025
PMID: 22794206

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 Jan;32(1):10-3.
DOI: 10.1016/j.joen.2005.10.007
PMID: 16410060

14. Silva EJ, Nejaim Y, Silva AV, Haiter-Neto F, Cohenca N. Evaluation of root canal configuration of mandibular molars in a Brazilian population by using cone-beam computed tomography: an in vivo study. J Endod. 2013 Jul;39(7):849-52.
DOI: 10.1016/j.joen.2013.04.030
PMID: 23791250

15. 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 Apr;6(1):72-81.
DOI: 10.14744/eej.2020.94695

16. Melton DC, Krell KV, Fuller MW. Anatomical and histological features of C-shaped canals in mandibular second molars. J Endod. 1991 Aug;17(8):384-8.
DOI: 10.1016/S0099-2399(06)81990-4
PMID: 1809802

17. Kato A, Ziegler A, Higuchi N, Nakata K, Nakamura H, Ohno N. Aetiology, incidence and morphology of the C-shaped root canal system and its impact on clinical endodontics. Int Endod J. 2014 Nov;47(11):1012-33.
DOI: 10.1111/iej.12256
PMID: 24483229 PMCID: PMC4258081

18. 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 Sep 1;21(1):424.
DOI: 10.1186/s12903-021-01787-7
PMID: 34470619 PMCID: PMC8411505

19. Helvacioglu-Yigit D, Sinanoglu A. Use of cone-beam computed tomography to evaluate C-shaped root canal systems in mandibular second molars in a Turkish subpopulation: a retrospective study. Int Endod J. 2013 Nov;46(11):1032-8.
DOI: 10.1111/iej.12094
PMID: 23521079

20. Alfawaz H, Alqedairi A, Alkhayyal AK, Almobarak AA, Alhusain MF, Martins JNR. 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. Clin Oral Investig. 2019 Jan;23(1):107-12.
DOI: 10.1007/s00784-018-2415-0
PMID: 29536188

21. 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 Oct;40(10):766-71.
DOI: 10.1111/j.1365-2591.2007.1283.x
PMID: 17714468

22. Joshi N, Shrestha S, Sundas S, Prajapati K, Devi Wagle S, Gharti A. C-Shaped Canal in Second Molar of Mandible among Cases of Cone Beam Computed Tomography in Tertiary Care Centres: A Descriptive Cross-sectional Study. JNMA J Nepal Med Assoc. 2021 Jul 30;59(239):649-52.
DOI: 10.31729/jnma.6722
PMID: 34508500 PMCID: PMC9107856

23. 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 Mar 16;2022:4886993.
DOI: 10.1155/2022/7825948
PMID: 35860794 PMCID: PMC9293536

24. 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 Apr 15;23(1):217.
DOI: 10.1186/s12903-023-02939-7
PMID: 37061674 PMCID: PMC10105946

25. Yang L, Han J, Wang Q, Wang Z, Yu X, Du Y. Variations of root and canal morphology of mandibular second molars in Chinese individuals: a cone-beam computed tomography study. BMC Oral Health. 2022 Jul 5;22(1):274.
DOI: 10.1186/s12903-022-02299-8
PMID: 35790917 PMCID: PMC9258086

26. Pawar AM, Pawar M, Kfir A, Singh S, Salve P, Thakur B, Neelakantan P. 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 Dec;21(9):2801-9.
DOI: 10.1007/s00784-017-2082-6
PMID: 28281013

27. Sabala CL, Benenati FW, Neas BR. Bilateral root or root canal aberrations in a dental school patient population. J Endod. 1994 Jan;20(1):38-42.
DOI: 10.1016/S0099-2399(06)80025-7
PMID: 8182385

28. Pereira B, Martins JNR, Baruwa AO, Meirinhos J, Gouveia J, Quaresma SA, Monroe A, Ginjeira A. Association between Endodontically Treated Maxillary and Mandibular Molars with Fused Roots and Periapical Lesions: A Cone-beam Computed Tomography Cross-sectional Study. J Endod. 2020 Jun;46(6):771-777.e1.
DOI: 10.1016/j.joen.2020.03.003
PMID: 32299702