A Cone – Beam Computed Tomographic Assessment of The Prevalance and Inter-orifice Distance of Second Mesiobuccal Canal Present in Maxillary First Molars in Lucknow Population – A Retrospective Study

Dr. Tanu Tewari[1*], Dr. Vishesh Gupta[2], Dr. Ria Saigal[3], Dr. Gunja Verma[4]

[1]Associate Professor, Department of Conservative Dentistry & Endodontics, Babu Banarasi Das College of Dental Sciences, BBD University, Lucknow, Uttar Pradesh, India*

[2]Professor & Head, Department of Conservative Dentistry & Endodontics, Babu Banarasi Das College of Dental Sciences, BBD University, Lucknow, Uttar Pradesh, India

[3]Junior Resident, Department of Conservative Dentistry & Endodontics, Babu Banarasi Das College of Dental Sciences, BBD University, Lucknow, Uttar Pradesh, India

[4]Junior Resident, Department of Conservative Dentistry & Endodontics, Babu Banarasi Das College of Dental Sciences, BBD University, Lucknow, Uttar Pradesh, India

*Corresponding Author:
Dr. Tanu Tewari
Associate Professor, Department of Conservative Dentistry & Endodontics, Babu Banarasi Das College of Dental Sciences, BBD University, Lucknow, Uttar Pradesh, India
Email ID: tanutewari@bbdu.ac.in

ABSTRACT

Aim and objectives: Using CBCT, ascertain MB2's incidence and inter-orifice distance of MB1-MB2 and MB2-PC in maxillary first molars in a specific Lucknow population using CBCT technique.

Methodology: One hundred CBCT scans of maxillary first molars meeting inclusion criteria were retrospectively analyzed. The presence or absence of the MB2 canal was recorded. For teeth with an MB2, the linear distances between the centres of the MB2 and MB1 orifices and between the MB2 and PC orifices were measured at the pulpal floor level using specialised 3D imaging software. Data were analyzed using descriptive statistics and chi-square tests.

Results: The MB2 canal was present in 68% of the studied maxillary first molars. The mean inter-orifice distance between MB1 and MB2 was 2.03 ± 0.50 mm, ranging from 0.70 mm to 3.80 mm. The mean distance between MB2 and the Palatal Canal was 4.92 ± 0.92 mm, ranging from 3.3 mm to 6.5 mm. The high prevalence confirms the MB2 as a common anatomical feature in this population.

Conclusion: The MB2 canal is highly prevalent in the maxillary first molars of the Lucknow population. The measured inter-orifice distances provide clinically valuable, population-specific guidelines for access cavity modification and targeted troughing, promoting a proactive "search and treat" approach to improve detection rates and the long-term success of endodontic therapy.

Keywords: MB2 canal, Cone-beam computed tomography, Prevalence, Inter-orifice distance, Maxillary first molar, Root canal anatomy.

Introduction

The goals of a good root canal treatment are excellent mechanical debridement of the root canal system and complete biological sealing of the canals for good periapical health and ensure long-term retention of the dentition.[1] The foundation for achieving these goals rest upon a profound understanding of the structure of the root.[2]

The maxillary first molar possesses one of the most complex and challenging structures for endodontic treatment of any tooth. It typically features three roots: two buccal (mesiobuccal and distobuccal) and one palatal.[3]The second mesiobuccal (MB2) canal is the most commonly overlooked canal in clinical practice, its high prevalence in the mesiobuccal root has been well-documented for decades.[4,5]

The complexity of the MB root was first systematically classified by Vertucci (1984)[4], who described eight different canal configurations. Type IV, one of the most frequent MB root topologies, has two discrete canals from the pulp chamber to the apex, whereas Type I in this categorisation reflects a single canal from pulp chamber to apex. Therefore, the existence of an MB2 canal—which may be a component of a Type II, III, IV, or other complicated configuration—is a common anatomical reality rather than an oddity. The MB2 orifice usually occurs mesiopalatally to the main mesiobuccal (MB1) canal. It can often be hidden below a dentinal shelf or within a groove referred to as the "mesiopalatal groove," making it tough to spot clinically without cautious access cavity modification and superior visualisation.[6,7]

The clinical significance of the MB2 canal cannot be overstated. An untreated MB2 canal serves as a potential reservoir for microorganisms and necrotic tissue, which can perpetuate periradicular inflammation and lead to the failure of an otherwise technically perfect endodontic treatment on the MB1, distobuccal, and palatal canals.[8] Evidence has shown that many root canal treatments in maxillary 1st permanent molars fail due to the inability of the dentist to locate and treat the MB2 canals.[9] Consequently, the pursuit of the MB2 is considered a standard of care in modern endodontics, necessitating a shift from a "see and treat" approach to a "search and treat" philosophy, guided by the knowledge of its high probability of existence.

The emergence of three-dimensional imaging has profoundly reshaped how root canal anatomy is explored. Micro-computed tomography (micro-CT) is considered the current gold standard for ex-vivo anatomical studies, providing sub-micron resolution and allowing for detailed 3D reconstructions and quantitative analyses of the internal and external morphology of teeth.[10,11,12] However, its high radiation dose and ex-vivo nature preclude its use in clinical patient care.

CBCT is a very potent in assessing complicated root canal systems. Compared to medical CT scanners, CBCT offers high-resolution, sub-millimeter, three-dimensional volumetric data at a far lower effective radiation dosage.[13] This technology allows clinicians and researchers to visualize the root canal system in axial, coronal, and sagittal planes, effectively "unfolding" the complex anatomy and eliminating the superimposition of structures. CBCT enables the clear identification of additional canals, isthmuses, canal fusions, and complex configurations that are undetectable on conventional radiographs.[14] Consequently, CBCT is now regarded as the gold-standard imaging tool for determining the existence of MB2 canal before starting root canal treatment.[11]

Numerous studies performed worldwide employing CBCT technology have examined the MB2 canal's occurrence in maxillary first molar teeth, highlighting extensive regional and ethnic variance. An overall pooled prevalence of 73.8% was discovered in a study that examined 5250 maxillary first molars from a global population, with a wide variation from 48% in a Venezuelan population to 97.6% in a Belgian population.[15] This highlights that the likelihood of finding an MB2 is highly population-specific.

Focusing on the Indian subcontinent, the data, though growing, is still emerging and exhibits regional variations. MB2 canals were found to be highly prevalent (61.9%) in a study on a Karnataka population. Age 20–40 years had highest prevalence of MB2 (67.4%), followed by those over 40 (57.5%), and those under 20 (50.6%),[16] underscoring its common occurrence and the need for clinicians to anticipate its presence. However, given India's vast genetic and ethnic diversity, findings from one region cannot be universally extrapolated. The population of Lucknow, in North-Central India, represents a distinct demographic that warrants specific investigation to provide locally relevant clinical data for practitioners in that region.

The inter-orifice distance between the MB1 and MB2 canals is a crucial clinical criterion in addition to the MB2 canal's presence or absence. Clinicians can use the accurate measurement of this distance as a quantitative guidance when preparing and troughing access cavities. Knowing the average distance and its range helps in directing the search for the MB2 orifice efficiently, minimizing unnecessary removal of dentin and reducing the risk of perforation. Studies have consistently shown that the MB2 orifice is typically located approximately 1-3 mm mesially and 2-4 mm palatally from the MB1 orifice.[7,17] For instance, a CBCT study by Al-Habib and Howait (2021)[18] in a Saudi subpopulation not only assessed the prevalence but also measured the inter-orifice distance, providing valuable clinical benchmarks. Similar quantitative data specific to the Indian population, particularly from Lucknow, is sparse and constitutes a significant gap that this research aims to fill.

Thus, the purpose of this study is to evaluate the prevalence of the second mesiobuccal (MB2) canal and MB1-MB2, MB2-PC orifice distance in maxillary first molars of a specific Lucknow population with the help of CBCT imaging. The results of this study will offer solid, locally applicable epidemiological data that can directly influence the clinical practice of general dentists and endodontists in the area. It will emphasise how crucial it is to anticipate the MB2 canal, direct the degree of access cavity modification and troughing, and eventually help increase the success rates of endodontic therapy for the maxillary first molar.

Materials and methodology

This study sought to determine the prevalence of the MB2 canal in maxillary first molars as well as measure the orifice distance between MB2-MB1 and MB2-PC in maxillary first molars in the Indian population from Lucknow. The Institutional Ethical Committee gave its clearance for this investigation. The Department of Oral Medicine and Radiology at Babu Banarasi Das College of Dental Sciences, BBDU, Lucknow, provided the CBCT images. Specialised imaging software was used to recreate and analyse the images.

Materials/Equipments used

- Cone□beam computed tomography unit (Vatech Smart Plus, South Korea)
- Ez3D□i imaging software (Vatech Smart Plus, South Korea) for reconstruction and measurement in coronal, axial, and sagittal planes

Methodology

The study included 100 CBCT images of maxillary first molars that satisfied the qualifying requirements. The existence of MB2 canal was assessed for each scan. Using specialised software, the second mesiobuccal canals' inter-orifice distance from the mesiobuccal (MB1) and palatal canals was then determined at the pulpal floor level.

Inclusion criteria:

1. Indian citizens residing in Lucknow city.
2. Age range 20–40 years.
3. Permanent maxillary first molars with fully developed roots.

Exclusion criteria:

1. Teeth with developmental anomalies, fractures, endodontic surgery, or calcification.
2. Teeth previously subjected to endodontic treatment.
3. Presence of fixed prosthesis in the maxillary first molar region.
4. Poor□quality CBCT images or absence of maxillary first molar in the scan.

Sample preparation and analysis

CBCT scans were obtained from the department's archive database. Ez3D-i software was used to rebuild each scan. The MB1, MB2, and palatal canal orifices were located using multi-planar reconstructions (axial, coronal, and sagittal). The following characteristics were noted:

1. Prevalence of MB2 canal – noted as present or absent in the mesiobuccal root.
2. Inter□orifice distance – linear distance (in millimeters) between the centers of the MB2 and MB1 orifices and PC and MB2 orifices at the pulpal floor level, measured using the software's measurement tool.

One calibrated examiner conducted every measurement. Twenty percent of the samples were reevaluated after a two-week period in order to evaluate intra-examiner reliability.

Results

Table – 1 Prevalence of MB2

2nd MesioBuccal canal (MB2)	No. (N=100)	%	95% CI for prevalence of MB2
Absent	32	32.0	(58.86-77.14)
Present	68	68.0	

The prevalence of the second mesiobuccal canal (MB2) was assessed in a total of 100 maxillary molars. The MB2 canal was present in 68% of the cases, while it was absent in 32%.

The estimated prevalence of MB2 was 68.0%, with a 95% confidence interval ranging from 58.86% to 77.14%, indicating that more than half of the maxillary molars in the study population exhibited an MB2 canal.

Overall, these findings highlight a high prevalence of the MB2 canal, underscoring the clinical importance of careful exploration and detection of this canal during endodontic treatment to ensure complete canal debridement and improve treatment outcomes.

Table – 2 Descriptive Summary of Inter orifice distance between 2nd MesioBuccal (MB2) and Mesiobuccal (MB1) canal

Parameter		Inter orifice distance bw 2nd MesioBuccal (MB2) and Mesiobuccal (MB1) canal
Mean		2.03
SD		0.50
95% CI	Lower	1.91
	Upper	2.15
Minimum		0.70
Maximum		3.80

The inter-orifice distance between the mesiobuccal (MB1) and second mesiobuccal (MB2) canals was evaluated to understand their spatial relationship. The mean inter-orifice distance was 2.03 mm, with a standard deviation of 0.50 mm, indicating moderate variability among the samples.
The 95% confidence interval for the mean distance ranged from 1.91 mm to 2.15 mm, suggesting that the true average distance in the population is likely to lie within this narrow range. The minimum recorded distance was 0.70 mm, while the maximum distance was 3.80 mm, reflecting considerable anatomical variation.
Overall, these findings demonstrate that the MB2 canal is typically located approximately 2 mm from the MB1 canal, but with notable variability. This information is clinically relevant for endodontic procedures, as awareness of this average distance and its range may aid in more accurate and efficient localization of the MB2 canal during access cavity preparation.

Table – 3 Descriptive Summary of Inter orifice distance between Second MesioBuccal (MB2) and Palatal canal (PC)

Parameter		Inter orifice distance bw 2nd MesioBuccal (MB2) and Palatal canal (PC)
Mean		4.919
SD		.9206
95% CI	Lower	4.696
	Upper	5.142
Minimum		3.3
Maximum		6.5

The spatial relationship between the second mesiobuccal (MB2) canal and the palatal canal (PC) was assessed by measuring the inter-orifice distance. The mean distance between MB2 and PC was 4.92 mm, with a standard deviation of 0.92 mm, indicating moderate anatomical variability.
The 95% confidence interval for the mean ranged from 4.70 mm to 5.14 mm, suggesting that the true population mean is likely to fall within this range. The minimum recorded distance was 3.3 mm, while the maximum distance reached 6.5 mm, reflecting a wide range of anatomical presentations.
Overall, these findings show that the MB2 canal is typically located approximately 5 mm from the palatal canal. Knowledge of this average distance and its variability is clinically important, as it can assist clinicians in accurately locating the MB2 canal during endodontic access preparation and reduce the risk of missed canals.

Discussion

The ultimate goal of endodontic therapy is to establish periapical health and long-term retention of the native tooth by completely debridement and closing the root canal system.[1] This goal requires a deep understanding of root canal anatomy. A significant clinical problem is the maxillary first molar's intricate mesiobuccal (MB) root structure. If left untreated, a second mesiobuccal (MB2) canal is a common cause of endodontic failure and persistent apical periodontitis.[2,8] CBCT was used in this investigation to evaluate the orifice distances between MB1-MB2 and MB2-PC, as well as to determine the prevalence of the MB2 canal in a population in Lucknow, India. The results revealed an MB2 prevalence of 68.0%, with mean inter□orifice distances of 2.03 ± 0.50 mm (MB2–MB1) and 4.92 ± 0.92 mm (MB2–PC).
The finding of a 68.0% prevalence of MB2 canals in the present study aligns closely with several CBCT-based investigations conducted in Indian populations. Neelakantan et al. (2010)[17], in a CBCT study of an Indian cohort, reported a 68.7% prevalence of MB2 canals, a figure nearly identical to our findings. Similarly, Singh and Pawar (2015)[36], in a North Indian population, found a prevalence of 63.3%. Another Indian study by Kewalramani et al. (2019)[16] in a Karnataka population reported a prevalence of 61.9% in three-rooted molars. These consistent results across different regions of India underscore that the MB2 canal is a common anatomical feature. Globally, a large multicenter CBCT study by Martins et al. (2018)[15] involving 5,250 maxillary first molars from 21 regions reported a pooled worldwide MB2 prevalence of 73.8%, further validating the high frequency of this canal, albeit with significant geographical variation.
The mean inter□orifice distance of 2.03 mm between the MB1 and MB2 orifices observed in our study provides valuable clinical guidance. This measurement is in strong agreement with other CBCT studies that have quantified this parameter. Al□Habib and Howait (2021)[18], in a Saudi subpopulation, found a mean

MB1–MB2 distance of 1.98 mm at the pulpal floor level. Normando et al. (2022)[45] in a Brazilian population reported an average distance of 2.0 mm.

This remarkable consistency across diverse populations suggests a relatively stable spatial relationship between these two orifices. Clinically, this implies that once the MB1 orifice is located, a focused search approximately 2 mm palatally and mesially—within a range of 0.70 to 3.80 mm as found in our study—is a rational and efficient approach to locating the MB2 orifice, minimizing unnecessary dentin removal.

Regarding the distance between the MB2 and Palatal (PC) canal, our study found a mean of 4.92 mm. Direct comparative studies reporting the MB2–PC distance is less common than those for MB1–MB2. However, this measurement contributes to a more comprehensive spatial mapping of the pulpal floor. Knowledge of this distance aids in defining the boundaries of the access cavity and troughing, ensuring that the search for the MB2 remains within the anatomical confines of the mesiobuccal root and does not encroach dangerously towards the palatal canal.

The mean inter-orifice distance between the MB2 and palatal canal (PC) measured in this Lucknow population was 4.919 ± 0.9206 mm. This specific metric provides a crucial third point for spatial mapping of the pulp chamber floor in maxillary first molars. When contextualized within the existing literature, this value demonstrates significant variation. It is markedly higher than the 0.74 ± 0.21 mm reported in a Saudi Arabian CBCT study,[44] indicating substantial demographic influences on anatomy. However, it aligns more closely with values from other Asian populations, such as the 3.96 mm (micro-CT) and 4.33 mm (micro-CT) reported in Chinese and Korean studies, respectively.[25,27] A critical observation is that while MB2 prevalence and MB1-MB2 distances have been frequently documented for Indian populations, a specific, directly comparable MB2-PC distance from a CBCT study in India is conspicuously absent from the current body of published literature. Therefore, the measurement presented here for the Lucknow cohort fills a specific gap, providing the first quantitative, CBCT-derived benchmark for this parameter within an Indian demographic. This new data enhances the preoperative anatomical blueprint available to clinicians, further aiding in defining the safe and effective boundaries for access cavity modification in this region.

While our findings are consistent with a substantial body of literature, it is important to acknowledge studies that have reported divergent results, primarily due to population-specific anatomical variations. For instance, a recent CBCT study in a Japanese population reported an MB2 prevalence of 52.9%[47], while a study in a Bruneian population found a prevalence of 51.3%[48]. Conversely, studies in some Asian populations have documented exceptionally high prevalence rates. Zheng et al. (2010)[25] in a Chinese population and Tian et al. (2016)[38] reported prevalences of 93% and 97.6%, respectively. The disparity highlights genuine ethnic and genetic differences in root canal morphology.

Furthermore, methodological factors such as CBCT scan parameters (voxel size), observer experience, and the precise criteria used to define a "canal" (e.g., detectable orifice vs. patent canal to apex) can influence reported prevalence rates.[17,42]

This study has immediate and important clinical consequences for practitioners in Lucknow and similar demographic contexts. The high prevalence (68.0%) confirms that the MB2 canal should be anticipated as the norm rather than the exception. The measured inter□orifice distances provide a practical, evidence□based guideline for access cavity modification. A rhomboid□shaped access with careful troughing approximately 2 mm palatomesial to the MB1 orifice, guided by the knowledge that the MB2 lies within a range of roughly 0.7–3.8 mm from the MB1, can significantly improve the detection rate. Failure to incorporate this "search and treat" philosophy, aided by knowledge of these metrics, risks leaving a necrotic tissue reservoir that compromises treatment outcomes.[16,18]

LIMITATIONS OF THE STUDY

This study has certain limitations. As a retrospective CBCT study, it reflects anatomical presence but not necessarily clinical negotiability. The sample was drawn from a specific regional population, which may limit direct extrapolation to all Indian demographics. Additionally, a single examiner completed all measurements; nevertheless, intra-examiner calibration was carried out to reduce bias.

CONCLUSION

In conclusion, this CBCT-based investigation discovered a high prevalence (68.0%) of MB2 canals in maxillary first molars, which is in line with the majority of recent Indian and international research. With a mean MB1–MB2 distance of 2.03 mm and a mean MB2–PC distance of 4.92 mm, it further set quantitative benchmarks for the inter-orifice distances. These findings reinforce the imperative for clinicians to actively seek the MB2 canal and provide a concrete spatial framework to do so effectively and safely. Future prospective clinical studies correlating these CBCT findings with actual clinical detection and negotiation success rates would further strengthen the translational value of this anatomical data.

ACKNOWLEDGEMENTS

The authors sincerely acknowledge the Department of Conservative Dentistry and Endodontics, Babu Banarasi Das College of Dental Sciences, Lucknow for providing the facilities and infrastructure required to conduct this study.

FUNDING

The authors received no external financial support for this study (Self Funded).

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to this study.

References

1. Schilder H. Cleaning and shaping the root canal. Dent Clin North Am. 1974;18:269-96.
2. Karabucak B, Bunes A, Chehoud C, Kohli MR, Setzer F. Prevalence of Apical Periodontitis in Endodontically Treated Premolars and Molars with Untreated Canal: A Cone-beam Computed Tomography Study. J Endod. 2016;42:538–41.
3. Cleghorn BM, Christie WH, Dong CCS. Root and root canal morphology of the human permanent maxillary first molar: a literature review. J Endod. 2006;32:813–21.
4. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol. 1984;58:589–99.
5. Stropko JJ. Canal morphology of maxillary molars: clinical observations of canal configurations. J Endod. 1999;25:446–50.
6. Kulild JC, Peters DD. Incidence and configuration of canal systems in the mesiobuccal root of maxillary first and second molars. J Endod. 1990;16:311–7.
7. Görduysus MO, Görduysus M, Friedman S. Operating microscope improves negotiation of second mesiobuccal canals in maxillary molars. J Endod. 2001;27:683–6.
8. Wolcott J, Ishley D, Kennedy W, Johnson S, Minnich S. Clinical investigation of second mesiobuccal canals in endodontically treated and retreated maxillary molars. J Endod. 2002;28:477–9.
9. Wolcott J, Ishley D, Kennedy W, Johnson S, Minnich S, Meyers J. A 5 yr clinical investigation of second mesiobuccal canals in endodontically treated and retreated maxillary molars. J Endod. 2005;31:262–4.
10. Ahmed HMA, Cheung GSP, Rossi-Fedele G, Dummer PMH. Application of a new system for classifying root and canal anatomy in studies involving micro-computed tomography and cone beam computed tomography: Explanation and elaboration. Int Endod J. 2021;54:1056–82.
11. Blattner TC, George N, Lee CC, Kumar V, Yelton CDJ. Efficacy of cone-beam computed tomography as a modality to accurately identify the presence of second mesiobuccal canals in maxillary first and second molars: a pilot study. J Endod. 2010;36:867–70.
12. Peters OA, Laib A, Rüegsegger P, Barbakow F. Three-dimensional analysis of root canal geometry by high-resolution computed tomography. J Dent Res. 2000;79:1405–9.
13. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc. 2006;72:75–80.
14. Michetti J, Maret D, Mallet JP, Diemer F. Validation of cone beam computed tomography as a tool to explore root canal anatomy. J Endod. 2010;36:1187–90.
15. Martins JNR, Marques D, Mata A, Carames J. Root and root canal morphology of the permanent dentition in a Caucasian population: a cone-beam computed tomography study. J Endod. 2017;50:1013–26.
16. Kewalramani R, Murthy CS, Gupta R. The second mesiobuccal canal in three-rooted maxillary first molar of Karnataka Indian sub-populations: A cone-beam computed tomography study. J Oral Biol Craniofac Res. 2019;9:347–51.
17. Neelakantan P, Subbarao C, Ahuja R, Subbarao CV, Gutmann JL. Cone-beam computed tomography study of root and canal morphology of maxillary first and second molars in an Indian population. J Endod. 2010;36:1622–7.
18. Al-Habib M, Howait M. Assessment of Mesiobuccal Canal Configuration, Prevalence and Inter-Orifice Distance at Different Root Thirds of Maxillary First Molars: A CBCT Study. Clin Cosmet Investig Dent. 2021;13:105–11.
19. Weine FS, Healey HJ, Gerstein H, Evanson L. Canal configuration in the mesiobuccal root of the maxillary first molar and its endodontic significance. Oral Surg Oral Med Oral Pathol. 1969;28:419–25.
20. Pomeranz HH, Fishelberg G. The secondary mesiobuccal canal of maxillary molars. J Am Dent Assoc. 1974;88:119–24.
21. Thomas RP, Moule AJ, Bryant R. Root canal morphology of maxillary permanent first molar teeth at various ages. Int Endod J. 1993;26:257–67.
22. Sempira HN, Hartwell GR. Frequency of second mesiobuccal canals in maxillary molars as determined by use of an operating microscope: a clinical study. J Endod. 2000;26:673–4.
23. Buhrley LJ, Barrows MJ, BeGole EA, Wenckus CS. Effect of magnification on locating the MB2 canal in maxillary molars. J Endod. 2002;28:324–7.
24. Huumonen S, Kvist T, Gröndahl K, Molander A. Diagnostic value of computed tomography in re-treatment of root fillings in maxillary molars. Int Endod J. 2006;39:827–33.

25. Zheng Q, Zhang L, Zhou X, Wang Q, Wang Y, Tang L, et al. A cone-beam computed tomography study of maxillary first permanent molar root and canal morphology in a Chinese population. J Endod. 2010;36:1480–4.
26. Kottoor J, Velmurugan N, Surendran S. Endodontic management of a maxillary first molar with eight root canal systems evaluated using cone-beam computed tomography scanning: a case report. J Endod. 2011;37:715–9.
27. Lee JH, Kim KD, Lee JK, Park W, Jeong JS, Lee Y, et al. Mesiobuccal root canal anatomy of Korean maxillary first and second molars by cone-beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011;111:785–91.
28. Gu Y, Lee JK, Spångberg LS, Lee Y, Park CM, Seo DG, et al. Minimum-intensity projection for in-depth morphology study of mesiobuccal root. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011;112:671–7.
29. de Toubes KMPS, Côrtes MIS, Valadares MA, Fonseca LC, Nunes E, Silveira FF. Comparative analysis of accessory mesial canal identification in mandibular first molars by using four different diagnostic methods. J Endod. 2012;38:436–41.
30. Reis AGAR, Grazziotin-Soares R, Barletta FB, Fontanella VR, Mahl CR. Second canal in mesiobuccal root of maxillary molars is correlated with root third and patient age: a cone-beam computed tomographic study. J Endod. 2013;39:588–92.
31. Paes da Silva Ramos Fernandes LM, Rice D, Silva EJNL, De-Deus G, Lopes RT, Souza EM, et al. Detection of various anatomic patterns of root canals in mandibular incisors using digital periapical radiography, 3 cone-beam computed tomographic scanners, and micro-computed tomographic imaging. J Endod. 2014;40:42–5.
32. Silva EJNL, Nejaim Y, Silva AI, Haiter-Neto F, Zaia AA, Cohenca N. Evaluation of root canal configuration of maxillary molars in a Brazilian population using cone-beam computed tomographic imaging: an in vivo study. J Endod. 2014;40:173–6.
33. Nur BG, Ok E, Altunsoy M, Aglarci OS, Colak M, Gungor E. Evaluation of the root and canal morphology of mandibular permanent molars in a south-eastern Turkish population using cone-beam computed tomography. Eur J Dent. 2014;8:154–9.
34. Somalinga Amardeep N, Raghu S, Natanasabapathy V. Root canal morphology of permanent maxillary and mandibular canines in Indian population using cone beam computed tomography. Anat Res Int. 2014;2014:731859.
35. Venskutonis T, Plotino G, Juodzbalys G, Mickevičienė L. The importance of cone-beam computed tomography in the management of endodontic problems: a review of the literature. J Endod. 2014;40:1895–1901.
36. Singh S, Pawar M. Root canal morphology of South Asian Indian maxillary molar teeth. Eur J Dent. 2015;9:133–44.
37. Mirmohammadi H, Mahdi L, Partovi P, Khademi A, Shemesh H, Hassan B. Accuracy of Cone-beam Computed Tomography in the Detection of a Second Mesiobuccal Root Canal in Endodontically Treated Teeth: An Ex Vivo Study. J Endod. 2015;41:1678–81.
38. 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;42:696–701.
39. Ghobashy AM, Nagy MM, Bayoumi AA. Evaluation of Root and Canal Morphology of Maxillary Permanent Molars in an Egyptian Population by Cone-beam Computed Tomography. J Endod. 2017;43:1089–92.
40. Arya S, Duhan J, Tewari S, Sangwan P, Ghalaut V, Aggarwal S. Healing of Apical Periodontitis after Nonsurgical Treatment in Patients with Type 2 Diabetes. J Endod. 2017;43:1623–27.
41. Studebaker B, Hollender L, Mancl L, Johnson JD, Paranjpe A. The Incidence of Second Mesiobuccal Canals Located in Maxillary Molars with the Aid of Cone-beam Computed Tomography. J Endod. 2018;44:565–70.
42. Martins JNR, Gu Y, Marques D, Francisco H, Caramês J. Worldwide Analyses of Maxillary First Molar Second Mesiobuccal Prevalence: A Multicenter Cone-beam Computed Tomographic Study. J Endod. 2018;44:1641-1649.e1.
43. Candeiro GT, Lopes L, Marques N, Moreira A, Aranha A, Rios M, et al. Internal configuration of maxillary molars in a subpopulation of Brazil's Northeast region: A CBCT analysis. Braz Oral Res. 2019;33:e082.
44. Alnowailaty Y, Alghamdi F. The Prevalence and Location of the Second Mesiobuccal Canals in Maxillary First and Second Molars Assessed by Cone-Beam Computed Tomography. Cureus. 2022;14:e24900.

45. Normando PHC, Santos JCMD, Akisue E, Paiva HC, Candeiro GTM. Location of the Second Mesiobuccal Canal of Maxillary Molars in a Brazilian Subpopulation: Analyzing Using Cone-beam Computed Tomography. J Contemp Dent Pract. 2022;23:979–83.
46. Karobari MI, Ahmed HMA, Khamis MFB, Ibrahim N, Noorani TY. Application of two systems to classify the root and canal morphology in the human dentition: A national survey in India. J Dent Educ. 2023;87:1089–98.
47. Watanabe S, Yabumoto S, Ikeda S, Okiji T. Evaluation of root and root canal morphology in maxillary first molar teeth: A cone-beam computed tomography study using two classification systems in a Japanese population. J Dent Sci. 2025;20:1554–1561.
48. Onn HY, Sikun MSYA, Abdul Rahman H, Dhaliwal JS. Prevalence of mesiobuccal-2 canals in maxillary first and second molars among the Bruneian population—CBCT analysis. BDJ Open. 2022;8:32.