Original Article

Middle mesial canal incidence and morphology in mandibular first molars: A cone-beam computed tomography and micro-computed tomography evaluation

Harpreet Singh, Renu Bala Sroa[1], Jagvinder Singh Mann[2]

Department of Conservative Dentistry and Endodontics, BJS Dental College, Hospital and Research Institute, Ludhiana, [1]Department of Conservative Dentistry and Endodontics, Government Dental College and Hospital, Amritsar, [2]Department of Conservative Dentistry and Endodontics, Government Dental College and Hospital, Patiala, Punjab, India

Abstract

Background: Mandibular first molar (MFM) being the first permanent posterior tooth to erupt, quite often gets involved in dental caries, which subsequently requires endodontic treatment in many cases. Thus, it is essential that the clinicians be aware of the root canal and the morphology of these teeth in detail. Over a period of years, the cases reporting with middle mesial canals (MMCs) in the MFMs have been seen on the rise; thus, it is imperative to know its incidence so that the data can be passed on to the clinicians for better management.

Aim: The aim of the current research was to evaluate the incidence of MMC in the MFMs using cone-beam computed tomography (CBCT) and further evaluating its morphology with micro-computed tomography (micro-CT).

Materials and Methods: Five hundred and fifty extracted permanent MFMs were collected and subjected to CBCT scan. The teeth in which MMC was found, were further subjected to micro-CT to evaluate the detailed morphology.

Observations and Results: The data exhibited the presence of MMC in 29 teeth out of 550 (5.27%). The most frequent morphological pattern observed in the MMC as per micro-CT was the confluent type (86.2%), followed by independent type (6.8%) and fin type (3.4%). Double MMC was observed in 1 tooth (3.4%).

Conclusion: The incidence of MMC was observed to be 5.27% and the confluent type of morphological configuration was the most common type noticed.

Keywords: Cone-beam computed tomography; incidence; mandibular first molars; micro-computed tomography; middle mesial canal

INTRODUCTION

With raised awareness toward the strategic importance of natural teeth among the general masses, the substantial value of endodontic therapy has reached a new horizon. The number of patients reporting to dental clinics for endodontic treatment and retreatment has increased inordinately in the past few decades. While there are many plausible reasons for endodontic failure, missed canals are one of the factors holding paramount importance.[1]

Of all teeth which are reporting to dental clinics with decay, mandibular first molars (MFMs) are the most frequent ones.[2]

Address for correspondence:
Dr. Harpreet Singh,
Department of Conservative Dentistry and Endodontics,
BJS Dental College Hospital and Research Institute, Ludhiana, Punjab, India.
E-mail: hsgentledental@gmail.com

Date of submission : 26.05.2024
Review completed : 15.07.2024
Date of acceptance : 16.07.2024
Published : 07.09.2024

Access this article online

Quick Response Code:

Website: https://journals.lww.com/jcde

DOI: 10.4103/JCDE.JCDE_319_24

How to cite this article: Singh H, Sroa RB, Mann JS. Middle mesial canal incidence and morphology in mandibular first molars: A cone-beam computed tomography and micro-computed tomography evaluation. J Conserv Dent Endod 2024;27:897-901.

This is probably because these are the first permanent teeth to erupt with deep pits and fissures, at about 6 years of age. These molars have deep developmental grooves which are more exaggerated and hence are more likely to develop caries.[2] Therefore, it is highly essential for the treating dental professional to have accurate knowledge about the root canal morphology of these teeth.

In general, MFM has two roots, namely mesial and distal, with the mesial root having two canals (mesiobuccal and mesiolingual) and the distal root having one canal (distal) or two canals (distobuccal and distolingual). Of significance in this aspect is the presence of an accessory third canal in the mesial root of certain teeth, named "Middle mesial canal" (MMC). Described in 1974 by Vertucci and William its prevalence across the world ranges from 1% to 46.2%.[3,4] Classified by Pomeranz *et al*. in 1981, it may be a confluent type, fin type, or independent one.[5]

The increase in reports of the presence of MMC is due to the increasing use of magnification and ultrasonics in endodontics on a routine basis.[6] However, one must understand that even under magnification, at times, accessory canals like MMCs can get missed. It, therefore, becomes essential to use other diagnostic methods to evaluate the actual incidence of such accessory canals.[7]

Cone-beam computed tomography (CBCT) is one of the ideal techniques to record any such anomaly present in the root canal system as it gives the details in three dimensions.[8] Further, to understand the root canal morphology in detail, micro-computed tomography (micro-CT), a nondestructive imaging tool which produces high-resolution three-dimensional (3D) images is recommended.[9] Hence, this research was undertaken to evaluate the incidence and detailed morphology of MMC in the regional population using CBCT and micro-CT, respectively.

MATERIALS AND METHODS

After obtaining the approval of the institutional ethical committee, 550 extracted permanent MFMs were collected from dental colleges and clinics in the state of Punjab, India. Teeth with two completely formed separate roots, no root caries, no root resorption, teeth with caries not involving the furcation area, and previously nonendodontically treated teeth were included in the study.

The collected teeth were stored in a formalin solution until evaluated. All the teeth were autoclaved to achieve sterilization. These teeth were then mounted in wax in horseshoe-shaped arches with 10 teeth mounted in each arch to facilitate the scanning of the teeth when subjected to CBCT. A total of 55 arches were made for the 550 teeth and the samples were numbered from 1 to 550. These teeth were then subjected to scanning using CBCT scanner (Sirona, Dentsply, USA), with the exposure settings of 9–14 mA, 110 kVp, 0.2–0.4 mm voxel size, exposure time of 6 s, and 17 cm × 20 cm field of view. The scans thus obtained were analyzed for the presence of MMC by visualizing the axial and the coronal scans. The number of teeth showing the presence of MMC was recorded.

The teeth exhibiting MMC on the CBCT scan were subsequently exposed to micro-CT utilizing a micro-CT Scanner (Metrotom 800, Zeiss, Germany) to thoroughly assess the configuration of MMC. The tomographic image acquisitions were made using ×0.4 optical magnification, over a 360° rotating angle and at the resolution of 6.5 µ with 1 s exposure rate for each projection. Zeiss Calypso software 2022, Deutschland, Germany was utilized for collecting the images and 3D rendering software Volume Graphics software, VGSTUDIO MAX 2024.1, Heidelberg, Germany, was used for the acquisition of images. The different types of MMC configurations observed were categorized according to Pomeranz *et al*. classification of MMC.[5]

OBSERVATIONS AND RESULTS

The CBCT scans of 550 teeth evaluated in the axial and coronal sections exhibited the presence of MMC in 29 teeth [Table 1].

Figure 1a-f depicts the CBCT scans of the arches, showing the presence of MMC in samples while Figure 2a-e depicts the micro-CT images of the samples showing different types of MMCs.

Out of 29 teeth, 25 teeth (86.2%) showed a confluent type of configuration for the MMC, out of which, it was observed to join the mesiobuccal canal in 18 teeth while it joined the mesiolingual canal in 7 teeth. Independent MMC was observed in 2 teeth (6.8%) and fin type configuration was observed in 1 tooth (3.4%). Double MMC was observed in 1 tooth (3.4%) [Table 2].

DISCUSSION

The prime objective of endodontic therapy is to achieve thorough disinfection of the root canal system, followed by its 3D obturation.[10] With the advent of modern technology,

Table 1: Middle mesial canal incidence in mandibular first molars

Sample evaluation	Observed number/ percentage
Total number of teeth evaluated	550
Number of teeth with MMC	29
Percentage of teeth with MMC	5.27

MMC: Middle mesial canal

Table 2: Middle mesial canal configuration in mandibular first molars in the sample group

Total number of teeth evaluated using micro CT	Confluent type (joining the mesiobuccal/mesiolingual canal) (Pomeranz classification), *n* (%)	Independent type (Pomeranz classification), *n* (%)	Fin type (Pomeranz classification), *n* (%)	Double MMC, *n* (%)
29	25 (86.2) Joining the mesiobuccal canal: 18 Joining the mesiolingual canal: 7	2 (6.8)	1 (3.4)	1 (3.4)

CT: Computed tomography, MMC: Middle mesial canal

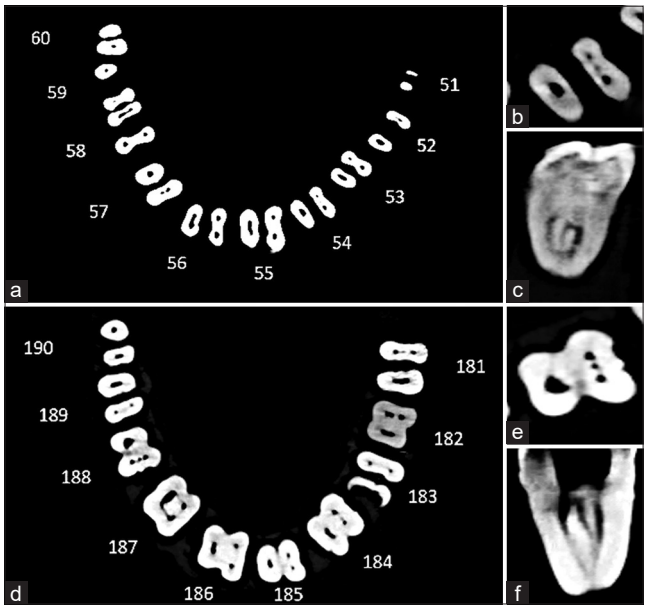

Figure 1: Cone-beam computed tomography scan showing the presence of the middle mesial canal in sample 54 (a), the closer axial (b) and coronal (c) views; middle mesial canal in sample 188 (d), the closer axial (e), and coronal (f) views

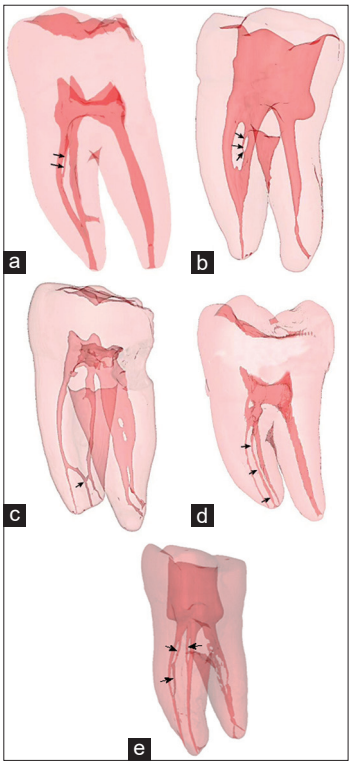

Figure 2: Micro-computed tomography images of the samples 34, 479, 252, 54, and 165 showing middle mesial canals "confluent type" joining the mesiobuccal canal (a), confluent type, joining the mesiolingual canal (b), "fin type" (c), "independent type" (d), and "double middle mesial canal (e)," respectively

in the arena of diagnosis, equipment, and material science, the success of endodontic treatment has substantially enhanced in the past few decades. However, what cannot be overlooked is failures do happen in endodontic therapy. Of all the factors that lie behind endodontic failures, it is perhaps the missed canals, which hold paramount significance.[1] The presence of anomalies such as additional canals, in the root canal system morphology pose a serious challenge to the clinicians and may affect the success rate of root canal treatment.

Previous investigations have indicated varying incidences of anatomical entities such as MMC and isthmus in the mesial root of permanent MFMs. An isthmus, also known as a lateral connection between canals of the same root, is a passageway that joins two larger structures or cavities. Microorganisms and organic waste can accumulate in the presence of an isthmus. The lack of recognition of the existence of an isthmus frequently results in endodontic therapy failures.[3]

MMC, often hidden in the isthmus, can be confluent type, fin type, or independent type. Confluent is when the MMC begins as a distinct orifice but apically joins with the mesiobuccal or mesiolingual canal. Fin is when an instrument can pass freely between the mesiobuccal or mesiolingual canal and the MMC while independent is when the MMC begins as a separate orifice and ends as a separate foramen.[3,4] In addition to these morphological variants of MMC, the severe curvature, present many times in MMC also poses a serious challenge to the treating clinician.

Thus, it is essential, that oral health care providers be aware of its incidence in their regional population to avoid missing it. The literature is full of methods which can be utilized to analyze the root canal configuration of teeth such as transverse and longitudinal sectioning, staining and clearing, stereomicroscopy, scanning electron microscopy, and 2D radiographic imaging.[11] What became a revolution in understanding the detailed root canal morphology was

the advent of CBCT. Because CBCT produced 3D data at a lower radiation dose and a higher spatial resolution than standard CT, it was widely accepted in the dental field.[8]

The CBCT scans of our 550 samples revealed the presence of MMC in 29 teeth (5.27%). The observations of our study are in consensus with those of Wang *et al*., who in their CBCT study in the Chinese population revealed that 2.6% of teeth had MMC in a sample of 558 mandibular molars.[12] Also Kim *et al*., after performing a retrospective analysis of CBCT of 1952 teeth in the Korean population, found MMC in 0.35% of mandibular molars.[13] Hasheminia *et al*. in their study on 768 MFMs in patients of Isfahan, using CBCT, found the MMC in 24 (3.13%) teeth.[14] Aldosimani *et al.* evaluated 687 MFMs in the CBCT scan and observed the MMC in 9 teeth (1.3%). They attributed the lower prevalence of MMC in their study to the use of strict criterion where MMC was noted only when it was seen in more than one plane.[15]

On the contrary, Nosrat *et al*., in their research work on mandibular first and second molars revealed a 20% incidence of MMC.[16] Furthermore, Azim *et al.* revealed the incidence of MMC to be 46.2% in mandibular molars when seen clinically after troughing, under the dental operating microscope.[17] It is imperative to note here that both these studies provided combined data of the mandibular first and second molars and not the former alone, as done in our study.

CBCT has its own set of limitations, especially in the context of identifying the canals in endodontics, the main ones being low image resolution (>200 μm voxel size).[18] The sharpness in the image is usually lacking, leading to a hard struggle of the investigator, who is trying to interpret the detailed root canal morphology.

Micro-CT has certainly brought a major revolution in the field of endodontics. Approximately one million times smaller volumetrically than the range on conventional CT, the voxel range of micro-CT is 5–50 μm. The small voxel range offers good cross-sectional resolution and provides detailed examination such as 3D multiplanar reconstruction of the entire tooth. Furthermore, there is the least likelihood of samples getting damaged during imaging and the measurements obtained are highly accurate.[19]

The 29 MFMs in our study which were subjected to micro-CT revealed that 25 teeth had the confluent type of configuration for the MMC, out of which, it was found to join the mesiobuccal canal in 18 teeth while it joined the mesiolingual canal in 7 teeth. Two teeth showed independent MMC and 1 tooth had fin type configuration of MMC. Double MMC was observed in 1 tooth. Undoubtedly, a limitation of our study is the lack of information regarding the age and gender of the subjects whose teeth were utilized in it. Another limitation is the use of a single observer who analyzed the CBCT and micro-CT scans.

Harris *et al*. reported MMC in 36.36% of the teeth. A small sample size ($n = 22$) of this study may be the reason for such a high incidence observed.[20] In a study by Marceliano-Alves *et al*., micro-CT scans of mesial roots of 104 MFMs of the Brazilian population were made which revealed MMC in 8 samples (7.7%).[21] There were 9 MMCs found in 58 MFMs (15.51%) in the study by Lamia and McDonald who used micro-CT for the evaluation of these teeth.[22]

MMC in MFM was assessed using micro-CT by Versiani *et al*., who studied its incidence in the Brazilian ($n = 136$) and Turkish ($n = 122$) population. Overall, the incidence of MMC in the Brazilian population was observed to be 22.1%, while it was 14.8% in the Turkish population. Confluent configuration of MMC was the most frequent anatomy observed in both population (83.3%), followed by fin type (8.30%), independent type (6.30%), and double MMC (2.10%). These results are similar to our study wherein confluent type configuration was more dominant (86.2%). However, in our study, independent type configuration was more (6.8%) as compared to fin type (3.4%), which is in contrast to the findings of this study. The incidence of double MMC found in our study (3.4%) is quite comparable to this study (2.10%). They also sub-classified the confluent type of configuration into confluent type with isthmus and confluent type without isthmus. The prevalence in their study was observed to be 29.20% with isthmus and 54.10% without isthmus. The higher overall incidence of MMC in this study may be accredited to the ethnicity of the population in which the study was conducted.[23]

Kyaw Moe *et al*. evaluated MMC in 75 MFMs using micro-CT. As per their observation, MMCs were found in 14 (18.7%) specimens, of which 57.1% were fin type, 21.4% were confluent type, and 21.4% were independent type of canals.[24] These results are quite in contrast to our study as in this research, fin type configuration was observed to be the highest, whereas in our study this configuration was found to be the least. The reason for this could be the varied ethnic composition of the research population. In a recent study, Farhad *et al.* evaluated the prevalence of MMC in 50 mandibular molars in an Iranian population using micro-CT and observed it in 36% of teeth.[25]

Although micro-CT has several advantages, its limiations include high cost, prolonged imaging time, its use being limited to laboratory study models/extracted teeth only, the need of special software for image reconstruction, utilization of large data storage space and the requirement of highly trained operators for handling complex hardware and software.[19] Notwithstanding the aforementioned drawbacks, micro-CT is still a very trustworthy technique for deciphering the minute details of the root canal system's morphology.

CONCLUSION

The incidence of 5.27% of MMCs in MFMs in our sample group indicates the need for careful management of these teeth when being treated endodontically. Furthermore, the higher chances of encountering a confluent type of MMC, when treating MFMs for endodontic therapy, must be kept in mind to ensure apt management.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Tabassum S, Khan FR. Failure of endodontic treatment: The usual suspects. Eur J Dent 2016;10:144-7.
2. Srivastava S, Alrogaibah NA, Aljarbou G. Cone-beam computed tomographic analysis of middle mesial canals and isthmus in mesial roots of mandibular first molars-prevalence and related factors. J Conserv Dent 2018;21:526-30.
3. Bansal R, Hegde S, Astekar M. Morphology and prevalence of middle canals in the mandibular molars: A systematic review. J Oral Maxillofac Pathol 2018;22:216-26.
4. Al-Rammahi HM, Chai WL, Nabhan MS, Ahmed HM. Root and canal anatomy of mandibular first molars using micro-computed tomography: A systematic review. BMC Oral Health 2023;23:339.
5. Pomeranz HH, Eidelman DL, Goldberg MG. Treatment considerations of the middle mesial canal of mandibular first and second molars. J Endod 1981;7:565-8.
6. Penukonda R, Pattar H, Nambiar P, Al-Haddad A. Middle mesial canal in mandibular first molar: A narrative review. Saudi Dent J 2023;35:468-75.
7. de Toubes KM, Côrtes MI, 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.
8. Kashyap RR, Beedubail SP, Kini R, Rao PK. Assessment of the number of root canals in the maxillary and mandibular molars: A radiographic study using cone beam computed tomography. J Conserv Dent 2017;20:288-91.
9. Jain RN, Abraham S, Karad RR, Najan HB, Vaswani SD, Torris A. Micro-computed tomographic analysis of the marginal adaptation of a calcium silicate-based cement to radicular dentin after removal of three different intracanal medicaments – An *in vitro* study. J Conserv Dent 2020;23:598-603.
10. Iandolo A, Abdellatif D, Pantaleo G, Sammartino P, Amato A. Conservative shaping combined with three-dimensional cleaning can be a powerful tool: Case series. J Conserv Dent 2020;23:648-52.
11. Ahmed HM. A critical analysis of laboratory and clinical research methods to study root and canal anatomy. Int Endod J 2022;55 Suppl 2:229-80.
12. Wang Y, Zheng QH, Zhou XD, Tang L, Wang Q, Zheng GN, *et al*. Evaluation of the root and canal morphology of mandibular first permanent molars in a Western Chinese population by cone-beam computed tomography. J Endod 2010;36:1786-9.
13. Kim SY, Kim BS, Woo J, Kim Y. Morphology of mandibular first molars analyzed by cone-beam computed tomography in a Korean population: Variations in the number of roots and canals. J Endod 2013;39:1516-21.
14. Hasheminia M, Razavian H, Khorrami L, Mosleh H, Mohamadi S. Prevalence of middle mesial canal in mandibular first molars using cone-beam computed tomography technique. Dent Res J (Isfahan) 2021;18:42.
15. Aldosimani MA, Althumairy RI, Alzahrani A, Aljarbou FA, Alkatheeri MS, AlGhizzi MA, *et al.* The mid-mesial canal prevalence in mandibular molars of a Saudi population: A cone-beam computed tomography study. Saudi Dent J 2021;33:581-6.
16. Nosrat A, Deschenes RJ, Tordik PA, Hicks ML, Fouad AF. Middle mesial canals in mandibular molars: Incidence and related factors. J Endod 2015;41:28-32.
17. Azim AA, Deutsch AS, Solomon CS. Prevalence of middle mesial canals in mandibular molars after guided troughing under high magnification: An *in vivo* investigation. J Endod 2015;41:164-8.
18. Taylor TT, Gans SI, Jones EM, Firestone AR, Johnston WM, Kim DG. Comparison of micro-CT and cone beam CT-based assessments for relative difference of grey level distribution in a human mandible. Dentomaxillofac Radiol 2013;42:25117764.
19. Ortiz FG, Jimeno EB. Analysis of the porosity of endodontic sealers through micro-computed tomography: A systematic review. J Conserv Dent 2018;21:238-42.
20. Harris SP, Bowles WR, Fok A, McClanahan SB. An anatomic investigation of the mandibular first molar using micro-computed tomography. J Endod 2013;39:1374-8.
21. Marceliano-Alves MF, Lima CO, Bastos LG, Bruno AM, Vidaurre F, Coutinho TM, *et al.* Mandibular mesial root canal morphology using micro-computed tomography in a Brazilian population. Aust Endod J 2019;45:51-6.
22. Lamia AF, McDonald NJ. Microcomputed tomographic evaluation of mandibular molars with single distal canals. Gen Dent 2015;63:33-7.
23. Versiani MA, Ordinola-Zapata R, Keleş A, Alcin H, Bramante CM, Pécora JD, *et al.* Middle mesial canals in mandibular first molars: A micro-CT study in different populations. Arch Oral Biol 2016;61:130-7.
24. Kyaw Moe MM, Ha JH, Jin MU, Kim YK, Kim SK. Anatomical profile of the mesial root of the Burmese mandibular first molar with Vertucci's type IV canal configuration. J Oral Sci 2017;59:469-74.
25. Farhad A, Hasheminia M, Hekmatian E, Mojiri V. Prevalence of middle mesial root canal in mandibular molars in an Iranian population: A micro-computed tomography study. Dent Res J (Isfahan) 2024;21:9.