Anatomical Investigation of Middle Mesial Canals of Mandibular Molars in a Middle Eastern Population: A Cross-sectional Cone-beam Computed Tomography Study

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Abstract

Aim: To identify the prevalence of middle mesial canals (MMC) in mandibular molars in a Lebanese population to determine the relationship between MMC and different factors (age, sex, and tooth type) and to examine the canal’s morphological aspects (category, length, orifice position, and dentin width toward furcation).

Materials and methods: The presence of MMC in the mesial roots of 505 mandibular molars of 200 patients was analyzed using cone-beam computed tomography (CBCT). Then, the position of the MMC orifices with respect to the pulpal floor and the main canals orifices, and the width of dentin along the canal toward the furcation were determined using 3D Slicer 4.10.1.

Results: In all, 14.65% of the first and second mandibular molars presented an MMC. A higher frequency of confluent canals was noted mostly joining the mesiobuccal canal (MBC). Gender appears to be a factor influencing the prevalence of MMCs, contrary to age-groups and tooth type. In mandibular first molars, the orifice is located at a mean distance of 1.22 ± 0.44 mm from the pulpal floor, 1.42 ± 0.53 mm from the MBC orifice, and 1.57 ± 0.60 mm from the mesiolingual canal (MLC) orifice. The width of dentin toward the furcation varies between 0.95 and 2.29 mm. In mandibular second molars, the orifice is located at a mean distance of 1.00 ± 0.51 mm from the pulpal floor, 1.39 ± 0.60 mm from the MBC orifice, and 1.37 ± 0.50 mm from MLC orifice. The width of dentin toward the furcation varies between 0.71 mm and 2.22 mm.

Conclusion: Middle mesial canal is present in 14.65% of mandibular molars in the Lebanese population, with its orifice located under the pulpal floor. The majority of MMCs join the MBC.

Clinical significance: Middle mesial canal is not a rare finding in the Lebanese population (14.65%). Clinicians should take time to search for this canal in the isthmus between the main mesial canals.

Keywords: Cone-beam computed tomography, Mandibular molar, Middle mesial canal, Morphology, Root canal anatomy.

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Introduction

Endodontic treatment must be preceded by a thorough knowledge of the anatomy of both the pulp chamber and the root canal system because access to the complete anatomy of the root canal system allows the eradication of microorganisms and their by-products, therefore enhancing the treatment outcome. This knowledge is particularly important when treating mandibular molars. In fact, the mesial root is associated with one of the highest degree of anatomical variability, hence the risk of treatment failure. The mesial root commonly presents 1 mesiobuccal canal (MB) and 1 mesiolingual canal (ML), but other anatomical configurations have been reported such as the presence of a third mesial canal between the two others. Vertucci and Williams were the first to demonstrate the presence of a third independent canal in the mesial root using the clearing technique. Later in 1981, Pomeranz published a comprehensive in vivo study describing the morphology and clinical management of this canal named middle mesial canal (MMC). Since then, many studies were published reporting this anatomical variation which has been found in a percentage frequency ranging from 0.2 to 46.15%. This percentage varies according to different authors, populations, and methods of evaluation such as clearing, plastic casts, conventional and digital radiography, scanning electron microscopy, microcomputed tomographic imaging (micro CT), and the use of file under magnification. Recently, cone-beam computed tomography (CBCT) technique has proved useful in providing accurate three-dimensional anatomical details of root and canal morphology while remaining noninvasive. In addition to that, to date, no studies have yet been conducted on the prevalence and morphology of MMC in a Lebanese population.

Therefore, the purpose of this study was to use CBCT radiographic imaging to:

- Record the prevalence and morphology of middle mesial canals in mandibular first and second molars in a Lebanese population.
- Correlate the prevalence of MMC with variables such as age, sex, and tooth type.
- Evaluate the distance from the MMC orifice to anatomic landmarks such as the mesiobuccal and mesiolingual orifices.

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Materials and Methods

Teeth Selection
This study was approved by the Ethics Committee of Saint Joseph University 2019-129.

CBCT images were retrieved from the database of the Radiology Department of Saint Joseph University (Beirut, Lebanon) and investigated retrospectively. The main purpose of the CBCT was the diagnostic imaging of maxillofacial tumors and cysts, the presurgical assessment of impacted teeth or orthodontic treatment and proposed implant sites. Therefore, the patients were not exposed to unnecessary radiation in order to obtain information on root canal anatomy and thus respecting the ALARA (as low as reasonably achievable) principle. In order to obtain clear images of the mandibular first and second molars, teeth were selected according to the following criteria: (i) mandibular first and second molars with no periapical lesions; (ii) no previous root canal treatments or metallic and heavy restorations; and (iii) no root canals with open apices, calcifications, and resorptions. Scans were chosen from consecutive patients in the database until a convenience sample of 505 mandibular first (242) and second molars (263) were collected from 200 Lebanese individuals (102 male and 98 female, mean age = 38.08 ± 15.1 years).

Radiographic Techniques
The CBCT scans were acquired using Newton VGI, QR SRL, Verona, Italy 9500 3D (Carestream Health, Inc., Marne-la-Vallée, France), operating at 90 kV and 10 mA with a voxel size of 0.2 mm. According to the examination requirements, a field of view of 70 × 120 mm was used. The scans were produced according to the manufacturer’s recommended protocol and the CBCT exposures were performed by a licensed radiologist with a minimum exposure necessary for adequate image quality.

Evaluation of the Images
The CBCT images were analyzed using the NNT 5.6 software (QR s.r.l via Silverstrini, 20-37135-Verona, Italy) with a 60 inch LCD screen with a resolution of 1920 × 1080 pixels in a dimly lit room. The contrast and brightness of the images were adjusted using the image processing tool in the software to ensure optimal visualization. All teeth were analyzed using three planes (sagittal, axial, and coronal) but mainly viewed on reconstructions according to the axial plane, scrolling the cursor in the coronal–apical direction, and then in the apical–coronal direction to get a detailed view of the root canal system. The teeth were also inspected in the sagittal and coronal plane in order to correlate the findings from the axial view and arrive at a conclusion. During examination of the teeth, the age and the sex of each patient were recorded.

The MM canal was recorded when a radiolucency was observed orifice, then separates in the middle third to join the main canal in the apical third.

1. The middle mesial canal leaves the pulp chamber as a separate canal and joins the MB canal in the middle or apical third.
2. The middle mesial canal leaves the pulp chamber as a separate canal and joins the ML canal in the middle or apical third.
3. The MMC orifice is connected to either the MCB or the MLC orifice, then separates in the middle third to join the main canal in the apical third.
4. Three independent canals extend from the pulp chamber to the apex.
5. Combination of (A) and (B): two distinct middle mesial canals: the first one leaves the pulp chamber as a separate canal and joins the MB canal in the middle or apical third, and the second one leaves the pulp chamber as a separate canal and joins the ML canal in the middle or apical third.

Figure 2 shows CBCT scans of the different MMC categories found.

Additionally, in the cases where a middle mesial canal was identified, the CBCT scans were converted into a DICOM format in order to process them using the measuring tool of the 3D Slicer 4.10.1 software. The following data were collected:

- Distance (in mm) from the MMC orifice to the MBC and MLC orifices using the axial plane.
- Distance (in mm) from the pulpal floor to the MMC orifice using the sagittal plane.
- Distance (in mm) from the orifice level to the confluence of the MMC to the other mesial canals or to its apical terminus using the axial plane.
- Width of dentin thickness (in mm) toward the furcation side along the canal trajectory using the sagittal plane. In this case, if the MMC joins one of the other canals in the middle third, two measurements were recorded:
  - A first measurement in the coronal third, 1 mm apically from the furcation.
  - A second measurement in the middle third, 1 mm coronally from the canal terminus.
- If the MMC joins one of the other canals apically or exits as an independent canal, three measurements were recorded:
  - A first measurement in the coronal third, 1 mm apically from the furcation.
  - A second measurement in the middle third, 1 mm coronally from the canal terminus.
  - A third measurement in the middle third, at an equidistance between the 2 others.

Evaluation was performed separately by two calibrated endodontists. A third experienced endodontist re-evaluated the radiographic images to confirm the data obtained and reach a consensus in the event of disagreement.

Statistical Analysis
The collected data were introduced into Excel (Microsoft, Redmond, WA) and analyzed with the help of Statistical Package Software for Social Sciences version 25.0 (SPSS for Windows, Version 25.0, Chicago, IL, USA) with a significance level set at p value ≤0.05.
The percentage of MMCs was recorded in the sample, and for age, sex and molar type, and their distribution among 5 categories, were also calculated. For each tooth type, the mean, mode and standard deviation were calculated for canal length, thickness of dentin toward furcation, and for the distance between the MMC’s orifice and the pulpal floor or the two other canal orifices. Correlations were studied using the Chi-square test. The Phi coefficient was used to calculate the strength of association.

**Results**

**Prevalence of MMC and Related Factors**

In all, 505 mandibular molars of 200 Lebanese patients were analyzed. Out of the 505 teeth, 74 (14.65%) presented with a middle mesial canal. Among these 74 canals, 53 (71.62%) showed “confluent” anatomy with the majority of the canals joining the MB canal (43.24%).

Figure 3 summarizes the distribution of the different morphological aspects of MMC.

The prevalence of MMC in mandibular first molars and mandibular second molars was 13.20% and 16.00%, respectively, with no statistically significant difference between the 2 teeth categories ($p$ value > 0.05). Table 1 shows the prevalence of MMC in different age groups. There was no statistically significant difference between age groups ($p$ value > 0.05). However, the prevalence of the MMC was significantly higher in the male group (18.40%) compared to the female group (11.20%) ($p$ value < 0.05); however, this association is weak (Phi < 0.10).

**Morphological Aspects of MMC**

**Mandibular First Molars**

The mean distances and range of values (in mm) between some anatomical landmarks and the MMC of mandibular first molars are illustrated in Table 2 and Figures 4 and 5. These measures were taken in the specimens with independent orifices (categories A, B, D, and E).

MMC orifice was found to be closer to the MBC orifice in 60.87% of the studied sample. The results showed no correlation between the distance of the MMC orifice to one of the main canals and its confluence to that same canal ($p$ value > 0.05).

**Mandibular Second Molars**

The mean distances and range of values (in mm) between some anatomical landmarks and the MMC of mandibular second molars are illustrated in Table 3 and Figures 4 and 5. These measures were taken in the specimens with independent orifices (categories A, B, D, and E).

MMC orifice was found to be equidistant to the MBC and MLC orifices (1.39 ± 0.60 mm and 1.37 ± 0.50 mm, respectively) but seems to join the buccal canal when the MMC orifice was located closer to the MBC orifice (83.30%) and the lingual canal when the MMC orifice was found to be closer to the MLC orifice (73.30%) ($p$ value < 0.05).

**Discussion**

The purpose of this study was to determine the prevalence of MMC in the Lebanese population, study the possible related factors, and describe its anatomy.

The prevalence of MMC in the literature varies between 0.26 and 46.2%. According to the present study, it is of 14.65% in the Lebanese population. This great difference can be attributed to
several factors, ranging from ethnicity to sample size and study design.

Several techniques for identifying and describing the MMC have been proposed in the literature. Among these is the clearing technique that causes irreversible changes in the tooth structure creating artifacts that further prevent a reliable and accurate representation of root canal morphology, particularly in the complex pulpal system of the mesial roots of mandibular molars. Low percentages were found when conventional 2D periapical radiographs or clearing technique were used. The highest proportion recorded in the literature was obtained by Azim et al. in a study conducted in vivo using a dental operation microscope. But in this study, there was no clear distinction between an isthmus and a true MMC. This factor may have accounted for the high numbers obtained. An ideal technique for anatomical investigations would be simple, accurate, three-dimensional, noninvasive, and more importantly feasible and reproducible in vivo. Recent imaging systems, CBCT and microCT, made it possible to evaluate three dimensionally the intricate internal anatomy. While being accurate, micro-CT is an in vitro technique that requires the extraction of the teeth to be evaluated. Its applicability remains limited due to the difficulty in collecting a sufficient number of extracted teeth of known origin for prevalence studies. Furthermore, micro-CT as well as the clearing technique do not take into consideration patient-related factors such as age and sex. No study has yet been published regarding the accuracy of CBCT in the detection of MMC. However, it has been found that using a CBCT with a voxel size of 200 μm was acceptable for the detection of MB2 canals in upper molars. For these reasons and for the purposes of the study, CBCT was chosen as the method of evaluation with a voxel size of 200 μm and image artifacts were reduced by excluding teeth with previous root canal treatment or metallic and heavy restorations.

Ethnicity seems to play a role in the prevalence of the MMC; Nosrat et al. conducted an in vivo study similar to the present CBCT study where they reported a prevalence of 20% MMC, which

| Age-group | <24 | 25–30 | 31–43 | >44 | Total |
|-----------|-----|-------|-------|-----|-------|
| Middle mesial canal | Yes | n | 19 | 20 | 13 | 22 | 74 |
| | % | 14.60 | 14.90 | 11.00 | 18.20 | 14.65 |
| No | n | 111 | 115 | 106 | 99 | 431 |
| | % | 85.40 | 85.10 | 89.00 | 81.80 | 85.35 |
| Total | n | 130 | 134 | 118 | 121 | 505 |
| | % | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

Table 2: Measurements (in mm) between some anatomical landmarks and the MMC of mandibular first molars

| Distance orifice-pulp floor | Canal length | Coronal third | Middle third | Apical third | Distance MMC-MLC | Distance MMC-MBC |
|-----------------------------|--------------|---------------|--------------|--------------|------------------|------------------|
| Mean | 1.22 | 4.94 | 1.56 | 1.39 | 1.35 | 1.57 | 1.42 |
| SD | 0.44 | 1.75 | 0.33 | 0.25 | 0.07 | 0.60 | 0.53 |
| Min | 0.60 | 2.18 | 1.05 | 0.95 | 1.27 | 0.79 | 0.66 |
| Max | 2.10 | 7.90 | 2.29 | 1.86 | 1.41 | 2.63 | 3.00 |

Figs 4A and B: Distances in mm between the orifices of the MMC and those of the ML and MB canals, and the pulpal floor in the (A) Mandibular first molar; (B) Mandibular second molar

Figs 5A and B: Dentin width in mm from the MMC toward furcation at 3 different levels in the (A) Mandibular first molar; (B) Mandibular second molar
is greater than the present numbers. This difference may be explained by the variations in ethnicity. In fact, a higher percentage of MMC was reported in Hispanic patients (40%) compared to black (27.6%) and Caucasian patients (12%). Versiani et al. also evaluated the influence of ethnicity on the prevalence of MMC and found a significant difference. The present results are similar to the ones obtained among the Turkish population (14.8%). MMC are less likely to be found among Asians. Studies indicate a prevalence of 0.26% and 0.82% in Korean and Chinese populations.

In addition to race, sex appears to be an influential factor in the anatomy and canal configuration. The present study shows that there is a significant difference between women (11.20%) and men (18.40%) ($p$ value < 0.05). In contrast, Nosrat et al. did not find a significant difference between women and men.

Age and tooth type do not seem to play a role in the prevalence of MMC.

**Location and Morphology**

Failure to locate and treat the MMC may compromise treatment outcomes, since the success of a root canal treatment depends on the complete disinfection of the entire root canal system. MMC orifices are located in the groove joining the MB and ML canals, but its exact location varies widely. In some cases they are located closer to one of the main canals, while in other cases, the MMC orifice is found to be equidistant to the main orifices. The present results show that the orifice of the MMC is located at a mean distance of 1.57 mm and 1 mm from the pulpal floor in the isthmus between the MB and the ML canals in mandibular first and second molars, respectively. The majority of the orifices were closer to the MB in accordance with de Toubes et al.

MMC orifices have been reported to lie under dentinal projection, which makes locating and accessing them a rather difficult task. A recent study suggested a troughing procedure for locating the MMC. This procedure consists of preparing a groove within a 2 mm depth between the orifices of the MB and ML canals. Many authors describe the “troughing technique” as a tool to locate the MMC orifice inside the isthmus. It consists of preparing the isthmus with ultrasonic tips or small round long neck burs up to 2 mm in depth. According to the present results, some orifices were located deeper than 2 mm while others were only at a 0.1 and 0.6 mm from the pulpal floor.

Karapinar-Kazandag et al. recommend a preparation depth of 0.7–1.1 mm up to 2.2 mm. Chavda and Garg insist that the troughing technique should only be applied under magnification in order to minimize the risk of strip perforations.

A new finding in the present study suggests a strong correlation between the position of the MMC orifice and the canal configuration in mandibular second molars. If the MMC orifice is found to be closer to one of the main canals, it’s more likely that the MMC joins this same canal. The results show that the most common morphology was the type A (in which MMC joins MB canal) followed, respectively, by B, C, D, and E which is in agreement with Versiani et al. who also found that in the majority of cases, the MMC joined with the MBC.

**Dentin Thickness**

This study’s findings show that the dentin thickness from the MMC toward the furcation can sometimes be less than 1 mm. Further studies should evaluate the degree of enlargement of the MMC in order to achieve optimal cleaning while minimizing the risk of stripping and perforations.

**Conclusion**

In conclusion, MMC are not a rare finding in the Lebanese population (14.65%). The majority seem to join the MBC. 4.05% of these MMC were independent canals; therefore, to treat or retreat mandibular permanent molars, especially in patients of Lebanese descent, dentists need to be aware of the possible existence of an MMC. Locating them is of high importance in order to achieve better cleaning of the complex root canal system. Clinicians should take time to search for this canal in the isthmus between the main mesial canals while referring to the anatomical description provided that shows that the orifices are located in the groove between the MBC and the MLC at variable depths below the pulpal floor.

**References**

1. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol 1984;58(5):589–599. DOI: 10.1016/0030-4220(84)90085-9.
2. Villas-Bôas MH, Bernardinelli N, Cavenago BC, et al. Micro-computed tomography study of the internal anatomy of mesial root canals of mandibular molars. J Endod 2011;37(12):1682–1686. DOI: 10.1016/j.joen.2011.08.001.
3. Vertucci FJ, Williams RG. Root canal anatomy of the mandibular first molar. J N J Dent Assoc 1974;45(3):27–28.
4. Pomeranz HH, Eidelman DL, Goldberg MG. Treatment considerations of the middle mesial canal of mandibular first and second molars. J Endod 1981;7(12):565–568. DOI: 10.1016/S0099-2399(81)80216-6.
5. Kim S-Y, Kim BS, Woo J, et al. 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(12):1516–1521. DOI: 10.1016/j.joen.2013.08.015.
6. 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(2):164–168. DOI: 10.1016/j.joen.2014.09.013.
7. Michetti J, Maret D, Mallet J-P, et al. Validation of cone beam computed tomography as a tool to explore root canal anatomy. J Endod 2010;36(7):1187–1190. DOI: 10.1016/j.joen.2010.03.029.
8. de Pablo OV, Estevez R, Péix Sánchez M, et al. Root anatomy and canal configuration of the permanent mandibular first molar: a systematic review. J Endod 2010;36(12):1919–1931. DOI: 10.1016/j.joen.2010.08.055.
9. Lee K-W, Kim Y, Perinpanayagam H, et al. Comparison of alternative image reformatting techniques in micro-computed tomography and tooth clearing for detailed canal morphology. J Endod 2014;40(3):417–422. DOI: 10.1016/j.joen.2013.09.014.
10. Ordinola-Zapata R, Bramante CM, Versiani MA, et al. Comparative accuracy of the clearing technique, CBCT and micro-CT methods in studying the mesial root canal configuration of mandibular first molars. Int Endod J 2017;50(1):90–96. DOI: 10.1111/iej.12593.
11. Neelakantan P, Subbarao C, Subbarao CV. Comparative evaluation of modified canal staining and clearing technique, cone-beam computed tomography, peripheral quantitative computed tomography, spiral computed tomography, and plain and contrast medium-enhanced digital radiography in studying root canal morphology. J Endod 2010;36(9):1547–1551. DOI: 10.1016/j.joen.2010.05.008.
12. Zhang R, Wang H, Tian YY, et al. Use of cone-beam computed tomography to evaluate root and canal morphology of mandibular molars in Chinese individuals. Int Endod J 2011;44(11):990–999. DOI: 10.1111/j.1365-2951.2011.01904.x.
13. Martins JNR, Marques D, Silva EJNL, et al. Prevalence studies on root canal anatomy using cone beam computed tomography imaging: a systematic review. J Endod 2019;45(4):372–386. DOI: 10.1016/j.joen.2018.12.016.
14. Nosrat A, Deschenes RJ, Tordik PA, et al. Middle mesial canals in mandibular molars: incidence and related factors. J Endod 2015;41(1):28–32. DOI: 10.1016/j.joen.2014.08.004.
15. Versiani MA, Ordinola-Zapata R, Keleş A, et al. Middle mesial canals in mandibular first molars: a micro-CT study in different populations. Arch Oral Biol 2016;61:130–137. DOI: 10.1016/j.archoralbio.2015.10.020.
16. Gu Y, Lu Q, Wang H, et al. Root canal morphology of permanent three-rooted mandibular first molars—part I: pulp floor and root canal system. J Endod 2010;36(6):990–994. DOI: 10.1016/j.joen.2010.02.030.
17. Keles A, Keskin C. Deviations of mesial root canals of mandibular first molar teeth at the apical third: a micro-computed tomographic study. J Endod 2018;44(6):1030–1032. DOI: 10.1016/j.joen.2018.02.028.
18. de Toubes KMP, de Souza Côrtes MI, de Abreu Valadares MA, et al. Comparative analysis of accessory mesial canal identification in mandibular first molars by using four different diagnostic methods. J Endod 2012;38(4):436–441. DOI: 10.1016/j.joen.2011.12.035.
19. Karapinar-Kazandag M, Basrani BR, Friedman S. The operating microscope enhances detection and negotiation of accessory mesial canals in mandibular molars. J Endod 2010;36(8):1289–1294. DOI: 10.1016/j.joen.2010.04.005.
20. Chavda SM, Garg SA. Advanced methods for identification of middle mesial canal in mandibular molars: an in vitro study. Endodontontology 2016;28(2):92–96. DOI: 10.4103/0970-7212.195425.
21. Fabra-Campos H. Unusual root anatomy of mandibular first molars. J Endod 1985;11(12):568–572. DOI: 10.1016/0099-2399(85)80204-1.
22. Martinez-Berna A, Badanelli P. Mandibular first molars with six root canals. J Endod 1985;11(8):348–352. DOI: 10.1016/0099-2399(85)80043-1.