To assess the occurrence of middle mesial canal using cone-beam computed tomography and dental operating microscope: An in vitro study

Manjiri Nagesh Honap, Darshana Devadiga¹, Mithra N. Hegde¹
Department of Conservative Dentistry and Endodontics, Chettinad Dental College and Research Institute, Kancheepuram, Tamil Nadu, ¹Department of Conservative Dentistry and Endodontics, A. B. Shetty Memorial Institute of Dental Sciences, Mangalore, Karnataka, India

Abstract
Introduction: Failures of root canal treatments are mainly attributed to missed canals and ignorance about the complex anatomy of the root canal system. One such example of anatomic variation is the middle mesial canal (MMC) in mandibular molars which is often missed, and literature on methods for identifying them is limited.

Aim: This in vitro study aimed to assess the occurrence of MMCs with cone-beam computed tomography (CBCT) and then under magnification in the mandibular first and second molars.

Materials and Methodology: A total of 120 extracted intact human permanent mandibular first and second molars were selected. These were subjected to CBCT imaging and magnification for the detection of MMCs. The percentage of incidence in the detection of MMC was compared between these two methods.

Results: The incidence of MMC detected in mandibular molars using CBCT was 13.33% (16 of 120 teeth), while using a dental operating microscope, the incidence was 18.33% (22 of 120 teeth) and the comparison between the two methods was statistically not significant.

The MMCs were classified based on the Pomeranz Classification. The most prevalent canal configuration was a confluent type which was found to be in 72% cases (16 of 22), followed by fin type which was 22.7% (5 of 22) and independent type was only 4.54% (1 of 22).

The incidence of the location of MMC orifice was studied. In 50% of the cases, orifice was located closer to the mesiolingual canal, whereas in 27% of the cases, it was closer to the mesiobuccal canal and in 4.95% of the cases, it was detected midway.

Conclusions: Since the incidence of MMC was higher with the use of a microscope, it is preferred to use simpler, chairside aids like magnification and ultrasonic troughing. On the other hand, one should be judicious while subjecting a case to preoperative CBCT evaluation owing to its ionizing radiation.

Keywords: Accessory canal; cone-beam computed tomography; mandibular molar; microscope; middle mesial canal

INTRODUCTION
Clinical endodontics encompasses a wide range of treatments with the common objective of preventing and treating microbial contamination of the pulp, root canal systems, and periradicular tissues.¹

It is imperative that the clinician has comprehensive knowledge about aberrant anatomy. A potential error at this phase unleashes a plethora of complications leading to compromised treatment prognosis. For example, failure
to locate all the canals may provide a persistent source of microbial contamination, altering long-term success of endodontic therapy.\[2\]

Karabucak et al. evaluated missed canal prevalence in endodontically treated teeth with the help of cone-beam computed tomography (CBCT); they concluded that the missed canal increases the possibility of developing a lesion in a tooth by 4.38 times.\[3\]

Mandibular molars are the most frequently treated teeth,\[4\] showing variations in anatomical forms such as C-shaped canals, isthmus, and an additional third canal in the mesial root, i.e., the middle mesial canal (MMC).\[5,6\] There is a high incidence of intercanal and intracanal communications in mandibular molars, reaching 83%, but success in accessing and negotiating the MMC is poor, ranging from 1% to 25%.\[8,9\] Despite being the most commonly treated tooth with a wide range of anatomic variations, the published literature available on the identification of MMC is scarce and thus was a choice in our study.

A detailed preoperative and intraoperative assessment of landmarks\[5,10,11\] would minimize the number of missed canals and therefore improve the percentage of clinical success.\[5,10\]

CBCT-based imaging technology overcomes many of the disadvantages of dental radiography. In this method, the operator can visualize the anatomy of the specimen in three-dimensional slices without destruction of specimen with greater image accuracy and resolution\[12\] offering a minimal X-ray dose and decreasing in imaging errors such as artifacts and superimposition.\[13,14\]

The resolution power of human unaided eye is 0.2 mm, which means two objects situated closer than 0.2 mm will appear as one. Optical aids such as dental operating microscopes (DOMs) (×3.5–25) can enhance the resolution of human eye by many orders of magnitude.

The studies discussing and comparing these preoperative CBCT assessment and intraoperative microscopic assessment methods for recording the incidence of MMCs are scarce; thus, we aimed to record the incidence of these MMCs in mandibular first and second molars using CBCT and DOM.

**MATERIALS AND METHODOLOGY**

This *in vitro* study was carried out in the Department of Conservative Dentistry and Endodontics, A. B. Shetty Memorial Institute of Dental Sciences, Deralakatte, Mangaluru, on 120 human intact permanent mandibular first and second molars extracted for periodontal reasons. Teeth with no developmental anomalies, absence of root canal fillings, and root decay were included in the study, while teeth with root resorption and fractured roots were excluded from the study.

**Step 1 Assessment of middle mesial canals using cone-beam computed tomography scan**

The selected mandibular molars were embedded into customized horseshoe-shaped blocks of modeling wax to

![Figure 1: Cone-beam computed tomography machine (PLANMECA PROMAX 3D mid)](image1)

![Figure 2: Teeth mounted in modelling wax to simulate jaw sets of 8 specimen teeth in each)](image2)

![Figure 3: Mounted teeth on cone-beam computed tomography machine for scanning)](image3)
simulate the form and shape of a human jaw for mounting on the CBCT machine with 15 sets of 8 specimens in each block [Figures 1-3]. The parameters used during CBCT exposure are mentioned in Table 1.

### Analysis of cone-beam computed tomography volumes

The CBCT volumes were analyzed in axial sections for locating the canals by using imaging software (Software Planmeca Romexis 3.4.0.R, Helsinki Finland) following the manufacturer’s guidelines [Figure 4]. The enlarged view of axial section shown in Figure 5.

| Exposure parameter for CBCT volume | value |
|-----------------------------------|-------|
| FOV (cm)                          | 5 x 5 |
| Kv                                | 90    |
| mA                                | 8     |
| Second                            | 12    |
| mGy cm²                           | 610   |

FOV: Field of View

The volumes were observed by two evaluators; Cohen’s kappa value was determined for interobserver reliability. There was a strong agreement between the two observers, \( \kappa = 0.784 (P < 0.001) \).

### Step 2 For intraoperative location of middle mesial canals using dental operating microscope

All teeth were demounted from the wax models used for CBCT scan and embedded in rectangular wax blocks [Figures 6 and 7]. Standard endodontic access cavities based on the principles stated by Krasner and Rankow in 2004[15] were prepared using airotor handpiece with an Endo Access bur.

The teeth in which mesial subpulpal groove was located, the preparation was further modified using standardized

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**Figure 4:** Axial sections as viewed in cone-beam computed tomography software (PLANMECA ROMEXIS version 3.4.0.R) Inset showing presence of three canals in the mesial root of the mandibular molar (mesiobuccal, mesiolingual, and middle mesial canal)

**Figure 5:** Enlarged view of axial section showing middle mesial canal

**Figure 6:** Dental operating microscope Carl Zeiss OPMI Pico

**Figure 7:** Sample preparation for endodontic access under microscope
guided troughing method. The ultrasonic tips were used to perform the guided troughing. Figures 8 and 9 at the expense of the mesio-axial wall. This was done by moving the entire isthmus away from the furcation region mesially and apically to detect the presence of MMCs [Figure 10] which were negotiated using #8 and #10 K-files.

**Analysis access cavities for the detection of middle mesial canals**

If MMCs were found, they were confirmed radiographically [Figure 11].

**Statistical analysis**

The data for the occurrence of MMC were tabulated systematically to compare the two methods, i.e., DOM and CBCT, the data were subjected to nonparametric McNemar test. The statistical significance was set at $P < 0.05$.

**RESULTS**

The incidence of middle mesial canal detected using dental operating microscope was found to be 18.33% while using CBCT it was found to be 13.33% [Table 2] [Graph 1]. Statistical analysis was carried out using McNemar test [Table 3], but significant difference was noted between the two diagnostic aids [$p<0.05$].

**DISCUSSION**

In the present *in vitro* study, the incidence of MMCs in 120 mandibular molars was observed using two methods: imaging by CBCT and guided troughing done under DOM.

The incidence of MMCs detected using an operating microscope showed a higher percentage (18.33%) than that of CBCT (13.33%) [Table 2], which was statistically not significant [Table 3].

This is in agreement with an *in vitro* study on the incidence of MMCs in mandibular molars by Karapinar-Kazandag.
et al.\cite{9} using DOM which showed an incidence of 18% and 22% in the first and second mandibular molars, respectively. In the present study the the incidence of MMCs detected using CBCT was 13.3%. A study conducted by Akbarzadeh et al.\cite{10} showed comparable incidence of MMCs to be 14.7%.

The frequency of MMCs in an in vivo study observed using DOM by Sherwani et al.\cite{11} on different age groups of 11–30 years, 31–50 years, and patients >50 years was 36.6%, 22.6%, and 18.4%, respectively. Although the overall incidence of 28.3%, which was higher than the present study, our results were similar to the incidence seen in the elderly age group.

The results of our study are not in agreement with another in vivo study conducted by Azim et al.\cite{12} which showed a higher incidence of 46.2% of MMCs in mandibular molars after guided troughing under magnification using DOM. This may be due to the in vivo design of the study which included mandibular teeth from younger age group in contrast to the relatively aged teeth evaluated in our in vitro study.

Most in vivo studies include molars from all age groups including teeth from younger individuals, while in vitro studies are conducted mainly on molars extracted for periodontal reasons in the elderly age group. The location of MMCs in molars decreases in incidence due to the progressive age-related calcification process\cite{9,13} making it difficult to visualize, locate, and negotiate the accessory canals.

Our results are also in agreement with an in vitro study by De Toubes et al.\cite{7} which compared the efficacy of four diagnostic methods of clinical examination, digital radiography, DOM, and CBCT. Higher incidence of MMCs was detected using DOM (30%) compared to (27%) CBCT.

The MMC orifice is usually small\cite{14} with a mean minor diameter being three times smaller (0.16 mm) than the main mesial canals (0.50 mm) that lies underneath the dentinal projections which needs to be uncovered and hence is a technical challenge. The operator must frequently explore the mesial subpulpal groove and troughing in apical direction to visualize the mesial isthmus to detect and negotiate this accessory canal with an endodontic instrument.

Troughing of the mesial subpulpal groove when done under the guidance of magnified visualization by DOM not only helps in the location of the orifice of MMCs but also mapping its relation to the main mesial canal (mesiobuccal and mesiointal) which can be used by clinicians as a navigation guide for searching MMC in routine cases which must be the reason for more MMCs detected by DOM in our study.\cite{8}

The gold standard methods to study the anatomy of root canals are mainly destructive experimental methods performed in a laboratory\cite{15} which are not applicable in clinical scenarios. Hence, in our study to simulate the clinical scenario, we selected a preoperative and an intraoperative method of assessment for the detection of MMC which can be clinically executed.

Successful management of endodontic disease is reliant on preoperative assessment using diagnostic imaging techniques to provide critical information about the teeth and their surrounding anatomy. Periapical radiograph is one of the most common choices for preoperative assessment, but it carries certain limitations like compression of three-dimensional structures to two-dimensional imaging, geometric distortion, and anatomical superimposition.\cite{16}

In the past few decades, newer and more accurate methods have been introduced\cite{17} to enable the nondestructive evaluation of the anatomical variations and morphological

| MMC | Located | Not located | Percentage located |
|-----|---------|-------------|---------------------|
| CBCT | 16      | 104         | 13.33               |
| DOM  | 22      | 98          | 18.33               |

MM: Middle mesial canal, CBCT: Cone-beam computed tomography, DOM: Dental operating microscope

## Table 3: Statistical analysis using McNemar test between cone-beam computed tomography and DOM

| CBCT | DOM | Total |
|------|-----|-------|
|      | No  | Yes   |       |
| Count| 88  | 16    | 104   |
| Percent of total| 73.3| 13.3| 86.7 |
| Yes | Count| 10 | 6 | 16 |
| Percent of total| 8.3| 5.0| 13.3 |
| Total | Count| 98 | 22 | 120 |
| Percent of total| 81.7| 18.3| 100.0 |

McNemar test \(P=0.327\) not significant. CBCT: Cone-beam computed tomography, DOM: dental operating microscope

## Graph 1: The bar graph showing incidence of middle mesial canals detected using cone-beam computed tomography and dental operating microscope

![Graph 1](image-url)
characteristics of the roots; one of them is CBCT. It facilitates the clinician to preoperatively assess the anatomy of the tooth in different planes with the feasibility of manipulating the images; hence, this contemporary radiological imaging technique was included in our study because of its reliability over other traditional preoperative assessment methods of radiographic evaluation.[21]

DOM is another device that can enable the visualization and location of root canals as a result of its clear magnification, illumination, and significant field of view.[22] It facilitates improved intraoperative accessory canal identification and evaluation of root canal systems which gives it an edge over other routinely used methods such as clinical examination, dye tracing, or magnification using loupes.[22]

Troughing in the pulp chamber floor with visualization via DOM has been suggested by many authors to improve accessory root canal identification, and hence, troughing with the magnification was the method of choice in our study.[2,4,6,9] Ultrasonic tips were selected for troughing over the access modification burs because troughing in the floor of the pulp chamber at this level requires specialized instrument, clear visual field, precision, and caution to avoid perforating the floor and its complications.[23]

In our study, we chose an in vitro model as it is important to carry the novel methods in experimental conditions before testing in patients, especially when ionizing radiation is involved. However, there are certain drawbacks involved in an in vitro experiment as it cannot fully recreate the in vivo clinical conditions.

CONCLUSIONS

Although our study showed a lower incidence of MMC with the use of CBCT compared to DOM, the use of CBCT to study morphologic visualization of the canal trajectory cannot be disputed. This holds true specifically in the mid and apical thirds of the roots where visualization with DOM is limited only to the straight portion of the canal. However, it has been suggested[24] that not all canals can be detected with CBCT; thus, it should be used as an auxiliary method in identification rather than as a replacement for careful clinical scouting techniques.

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Conflicts of interest
There are no conflicts of interest.

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