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Prevalence of middle mesial canals and Isthmi in mandibular molars in a subpopulation of Andhra Pradesh: an *in vivo* investigation using CBCT

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ABSTRACT

Background: Pulp and root canal space is enigmatic and highly complex. Encountering rare has become a norm with the advancements in the technology of materials and types of equipment. The success of the root canal treatment depends on the effective removal of bacteria from the whole pulp space. A high percentage of the missed canal is reported for the failure of Endodontic therapy. Mandibular molars have complex root canal anatomy. Two roots with two canals in mesial root and one to two canals in distal root is a common occurrence. Nevertheless, the incidence of variation is relatively high, including separate distolingual, mesiobuccal, C-Shaped canals, isthmus, and additional canal in the mesial root. A wide range of the middle mesial canal occurrence, i.e., 3.1 to 46.1%, is reported in the world and 28.3% in North India.

Aim: To identify the prevalence of the true middle mesial canal (MM) and configuration of Isthmi in the mesial root of the mandibular molar in the AP subpopulation of South India.

Materials and methods: CBCT of 89 patients were randomly selected from the institutional database. Data entry was performed in Excel, and data analysis was done with the Statistical Package for Social Sciences (SPSS).

Results: Four images (4.5%) revealed Middle Mesial canals with no statically significant occurrence. The frequency of isthmi in the mesial roots was 52.7%. This showed a considerable presence.

Conclusion: MM canals are 4.5% in a subpopulation of Andhra Pradesh. Isthmuses are very common in the mesial roots of permanent mandibular molars. Isthmus about 58% was seen with Type II configuration that is the presence of two canals without a definite communication.

1. Introduction

For root canal treatment to be successful, it is necessary to locate all root canals, debride them thoroughly, and seal them completely [1]. The clinician should be aware of the internal morphology of permanent teeth and the possible variations, which may be encountered [1]. The mandibular 1st Molar is the first posterior tooth that erupts, and that most often requires root canal treatment [1]. Mandibular molars often present with complex root canal anatomy.

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Mandibular molars usually have two roots with three or four root canals. However, several variations, such as an additional distolingual or mesiobuccal (MB) root, a C-shaped root canal system, and isthmuses connecting the canals, may also be present [2,3]. Moreover, sometimes, a third canal may be present in the isthmus between the MB and mesiolingual (ML) canal known as the middle mesial (MM) canal.

The middle mesial canal is an occasional entity that lies in the developmental groove between mesiobuccal and mesiolingual canals. Pomeranz, Eidelman, Goldberg (1981) [4] classified MM canal into three categories; a) Fin: The file passes freely between the central mesial canal (ML or MB) and the MM canal (transverse anastomosis), b). Confluent: The MM canal merges with main mesial canals in the apical third, and c). Independent: The MM canal originates as a separate orifice and ends with a separate apical foramen [4].

Root canal isthmus, a narrow ribbon-shaped communication between two root canals, is an important anatomical feature because it may contain pulp remnants, necrotic tissues, and micro-organisms and their by-products [5]. An isthmus is also called a corridor, a lateral interconnection, and a transverse anastomosis [6]. The prevalence of isthmus varies according to tooth type [7], root levels [8], and age [9]. An isthmus might be found in roots with C-shaped canals or in two adjacent canals such as mesial roots of mandibular molars, premolars, and so on [5]. The mesial root of the mandibular first Molar exhibits the most number of isthmuses [7,10].

Magnification has improved the clinician's ability to locate and negotiate unusual root canal morphology. A study on mandibular molars revealed that a Dental Operating Microscope (DOM) enhances the probability of finding and negotiating MM canals [11]. A higher-magnification view of the straight segment of the root canal by using either magnifying glasses or an operating microscope (DOM), mainly, enhances the ability to detect canals that could not usually be observed by clinical inspection alone [12]. This has increased the number of published case reports showing unsuccessful endodontic treatment because Accessory Mesial Canals are not always visible without the aid of magnification [13].

Many morphological variations in the mandibular molar are encountered in routine endodontic practice in our department. When the literature search was done, limited in vivo studies have been reported about the prevalence of the middle mesial canal. Most of the studies are present in the western population and few in South Asia. *In vitro* clearing techniques of teeth have been used in North America, Africa, East, and West Asia populations to detect the middle mesial canal. The results showed a 7-23.3% presence of the middle mesial canal. With advances in imaging, the occurrence of the middle mesial canal is reported as 46.1%.

In vivo studies utilizing radiograph, CBCT, MICRO CT, guided troughing, and use of CBCT has been used for evaluating middle mesial canals in North America, South America, Europe, and South Asia. The Presence of the middle mesial canal in the range of 4-28% is recorded. An in vivo study was done in mandibular first molars with the utilization of ultrasonic tips and endodontic explorer under a Dental Operating Microscope in the north Indian population. 28.3% of the negotiable middle mesial canal has been reported in the study.

India is a vast country; a lot of geographic variation exists along with the different ethnic populations. There are no studies done on evaluating the Presence of the middle mesial canal and isthmus in the South Indian population. Hence, a study was designed to evaluate the prevalence of the middle mesial canal in the sub-population of Andhra Pradesh.

CBCT is an advanced digital imaging system that can render the three-dimensional information of hard tissues. There is a probability of missing the middle mesial canal in two-dimensional radiograph and Endodontics without magnification. Accurate evaluation and diagnosis can be made with CBCT; hence, this study was designed to evaluate the anatomical root canal diversity in mandibular mesial roots of the subpopulation of Andhra Pradesh. The prevalence and configuration of the middle mesial canal and isthmus in mandibular mesial roots analyzed using CBCT.

2. Materials and methods

The Institutional Review-Board approved the Ethical–approval protocol. From the patient's data bank of the Oral and Maxillofacial Radiology and Department of Conservative Dentistry and Endodontics, CBCT images of permanent mandibular first and second molars were taken as a part of a dental examination for diagnosis

and treatment planning purposes, from March 2018 to November 2018 were collected. Based on a previous study [4], a sample calculation was performed using 95% confidence intervals. Approximately 89 cases were needed to have a precision of 5%.

The CBCT images were taken using CRANEX 3D (Soredex, Tuusula, Finland) with a flat panel detector were collected. The scans were done at 90 kV and ten mA, as recommended by the manufacturer with different fields of view (FOV) 61×41mm, of standard resolution of 200µm voxel size with SCANORA^{Tm} Imaging Software 5.2 (Soredex, Tuusula, Finland), ON-DEMAND 3DTm Server (Soredex, Tuusula, Finland). ALL images of a small field of view (FOV) CBCT with exposure parameters 60-90 kVp and 6-15 mA were selected.

The CBCT images were viewed with SCANORA Imaging Software ON-DEMAND 3D 5.2 on a Dell Professional with a 22-inch Dell light-emitting diode monitor with a resolution of 1680 x 1050 pixels in a dimly lit room. The window/level of the images was adjusted using the image processing tool in the software to ensure optimal visualization. Two independent observers, an Oral and Maxillofacial Radiologist, and an Endodontist were calibrated based on the criteria and variants established before the evaluation session. All images were analyzed simultaneously to reach a consensus for the interpretation of the radiographic findings. Multi-planar images were interactively examined sequentially in all three dimensions, and results were correlated across these images to conclude.

Only the first and second permanent mandibular molars with no previous root canal treatment and/or full-coverage restoration were included in the study. Teeth with open apices, root resorption, or calcification were excluded from the study. All teeth were analyzed using three planes (sagittal, axial, and coronal). During the examination of the teeth, the number of roots, the number of root canals in the mesial root, and the configuration of the root canal system in the mesial root were determined and recorded. In the axial view, an isthmus was recorded when a narrow ribbon-shaped communication was visualized between the MB and ML canals. The MM canal was recorded when a radiolucency with a distinct round cross-section was visualized between the MB and ML canals regardless of the presence or absence of an isthmus (Figures 1-4).

Data collected were entered in an excel sheet, and analysis was performed with the help of the Statistical Package for Social Sciences version (IBM SPSS Statistical Package for Social Sciences 20.0, USA).

Middle mesial canal

Code 0 - Absence of Middle Mesial Canal.
Code 1 - Presence of Middle Mesial Canal.

Isthmus

Code 0 - Absence of Isthmus.
Code 1 - Presence of Isthmus up to Coronal Third.
Code 2 - Presence of Isthmus up to Middle Third.

System 3 - Presence of Isthmus up to Apical Third.

CBCT images were recorded in three planes in coronal, sagittal, and axial views. In the axial view, an isthmus was recorded when narrow ribbon shape communication was visualized between mesio-buccal and mesio-lingual canal. The MM canal was recorded when a radiolucency with distinct round cross-section visualized regardless of the presence or absence of isthmus.

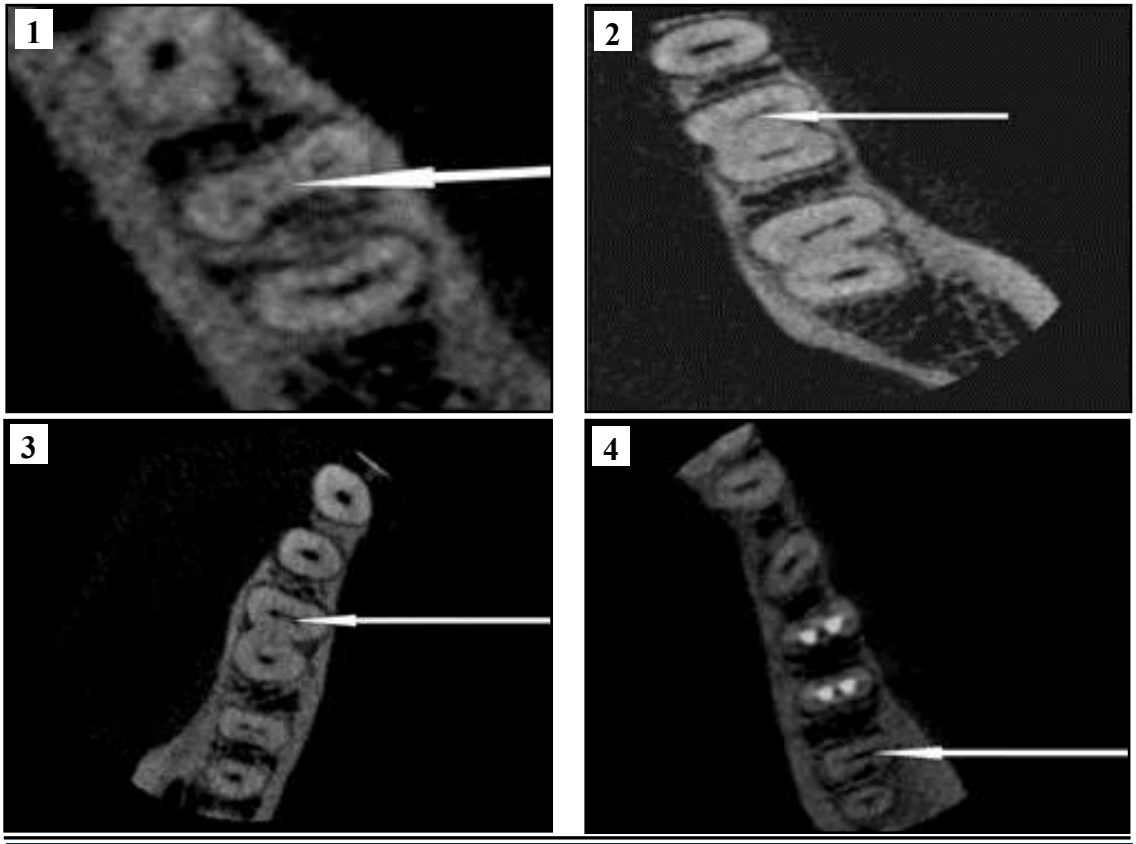
3. Results

A total of 89 CBCT images were analyzed (34 female 55 male patients). Of the 89 patients, four (4.5%) had Middle Mesial canals (Table 1). The frequency of isthmi in the mesial roots was 52.9% (Table 2). In twenty-seven molars (30.8%) isthmi were present in the coronal third, fifteen molars (16.7%) present in the middle third, four molars (5.4%) in the apical third. Prevalence of isthmi, based on the Kim classification Type II-30.3%, Type IV-16.9%, Type-V-5.4%. There was no statistically significant presence of MM canals. However, a statistically considerable Presence of isthmi in mandibular molars was seen.

4. Discussion

The success of root canal treatment primarily depends upon the complete disinfection of pulp canal space. Though there is abundant literature available regarding pulp and root canal architecture, it continues to be an enigmatic entity. Many variations exist, and one such occurrence is the middle mesial canal in a mandibular molar.

Mid mesial canal is an extra canal occurring between the mesio-buccal and mesio-lingual canal of the



Figures 1-4. CBCT images of mandibular molars. Where 1. middle mesial canal, 2. Isthmus in coronal third of mandibular molar, 3. Isthmus in middle third of mandibular molar, and 4. Isthmus in apical third of mandibular molar.

Table 1. Prevalence of middle mesial canal in mandibular molars

	Frequency	Percentage
Present	4	4.5
Not present	85	95.5
Total	89	100

Table 2. Prevalence Isthmus in Mandibular Molars

	Frequency	Percentage
Coronal 3rd	27	30.34
Middle third	15	16.85
Apical third	4	4.49
Not present	43	48.32
Total	89	100

mandibular mesial root. The middle canal orifice exists below a dentinal projection in the groove between the two main canals. The layer of dentin in this groove is lighter in colour than the adjacent dentin. Studies have reported the average length of the groove in mandibular first and second molars to be 1.07–2.81 mm and the average depth to be 1.05 mm and 0.17–7.66 mm [5].

Mid Mesial canal is an extra canal occurring between the mesio-buccal and mesio-lingual canal of the mandibular mesial root. The middle canal orifice exists below a dentinal projection in the groove between the two main canals. The layer of dentin in this groove is lighter in colour than the adjacent dentin. Studies have reported the average length of the groove in mandibular first and second molars to be 1.07–2.81 mm and the average depth to be 1.05 mm and 0.17–7.66 mm [5].

An isthmus is formed when an individual root projection is unable to close itself off, forming a constriction. The approximation of the root projections can fuse completely and form one root with one root canal system, as in the distobuccal root of maxillary molars. Alternately, partial fusion results in the formation of two root canals with an isthmus formed in between, such as the mesial root of the mandibular first Molar. No fusion leads to a large ribbon-shaped canal containing an isthmus throughout the entire root. It is a common finding in the distal root of the mandibular first molars and maxillary second premolars [10].

Many of the root canal investigations were *in vitro* studies using the clearing technique. Wang *et al.* (2010) [14] used CBCT and detected the MM canal in

2.3% of the population studied. However, these studies investigated root canal morphology only and did not aim for MM canal only. So, the prevalence of MM canals was analyzed from Vertucci's (1984) [8] classification with additional modifications. Currently, CBCT has been used in Endodontics to better understand the root canal system with the results conforming to the laboratory techniques [15,16].

The present study determined the prevalence and morphology of MM canals in permanent mandibular first and second molars based on CBCT images. In this study, scan settings of the studied CBCT images were at with different fields of view (FOV) 61×41mm and 61×78mm of standard resolution of 200µm and 300µm voxel size respectively for a clear image to investigate the root canal anatomy [17].

Geographical distribution of the middle mesial canal has been reported in Europeans, Asians, Africans, and South and North Americans. The findings of studies have also pointed to geographical differences. Nosrat *et al.* (2015) [18] found significant differences in the incidence of MMC between White (12.2%) and non-White (29.4%) patients and Brazilian and Turkish populations, respectively.

It has been shown that there is an association between untreated canals and isthmi and apical periodontitis. The untreated canals and isthmi can be covered with biofilm or even further clogged with bacteria in treated cases. Also, if not instrumented, these areas would not be reached by disinfecting irrigants [19]. Identifying the MMC isthmus with the help of CBCT and recent advances increases the success rate of root canal treatment.

In the present study, out of 89 Mandibular molars, MMC was found only in 4 (4.5%). According to Pomrerenz (1981) [4] classification in the present study, all four of the middle mesial canals are independent. In general, MM canals were classified based on Pomerenz's (1981) [4] classification as fin, confluent, and independent. The prevalence of MM canal in Asian populations was 1-13.3% [20-22]. Regarding the location of the MM canal orifice to the orifices of main mesial canals, it was found that in 4.5%of the cases, the MM canal orifice was located in the middle of the MB and ML canal orifices. These findings are inconsistent with previous studies that reported that the MM canal was located closer to the ML canal in the majority of the cases followed by the MM orifice located in the middle of MB and ML canals. In contrast, the least number of cases showed the orifice closer to the MB canal [23,24].

The management of root canal isthmus is essential in nonsurgical and surgical endodontic treatment [24]. Complete cleaning, shaping, and obturation of the apical third of root canals are considered among the most critical factors in achieving an excellent prognosis of root canal therapy. An unprepared isthmus in the root canal system, especially in the mandibular and maxillary molars, might contain necrotic debris and tissue remnants, which might serve as a reservoir for bacteria, leading to endodontic failure [7,24]. The difficulties in cleaning and shaping the mesiobuccal root canal system during conventional root canal treatment may lead to eventual failure necessitating retreatment. Therefore, initial anatomical knowledge, recognition, and proper management of an isthmus may be of great value to increase the success rate of surgical and nonsurgical endodontic treatments in posterior teeth [25-27].

In the present study, isthmuses were found in 58.9% of the mesial roots of the mandibular first and second molars. Isthmus present up to the coronal third was 30.3% middle third was 16.9%, and the apical third was 5.4% Teixeira *et al.* (2003) [28] found an incidence of 59% two canals in the mesial root of mandibular molars. Prevalence of isthmi, based on the Kim classification type2 -30.3%, type 4-16.9%, type-5-5.4%. The incidence of the isthmus was greatest 3-5 mm from the apex. In these cases, 22% were complete, and 37% partial in mandibular molars. Bidar M *et al.* (2006) [26] reported an isthmus incidence of 16% in distal roots with two canals of mandibular molars in a sample of the Iranian population.

Management of complete isthmus is more comfortable with the use of microsurgical techniques, such as the usage of a Dental Operating Microscope and microsurgical instruments. However, the preparation of incomplete isthmuses is more difficult and requires the proper use of fine ultrasonic tips [29]. A recent study found that the residual bacteria which frequently are entrapped in ramifications, isthmuses, and dentinal tubules makes it necessary to use an antibacterial irrigant and inter appointment medicament to maximize bacterial reduction before filling of the infected teeth [30].

However, the complete eradication of bacteria could not be achieved in the apical isthmus after two sessions of endodontic therapy [30]. Although various studies on the evaluation and management of isthmuses and recent advances in nonsurgical endodontic treatment modalities such as modern sonic and ultrasonic irrigation devices, side-vented needle irrigation (SNI), and VPro EndoSafe (VPro), cleaning and shaping of isthmus areas is still challenging [31,32]. Susin *et al*. (2010) [33] showed that the application of negative pressure techniques for the removal of debris from the isthmus in the mesial root of a mandibular first molar does not lead to the removal of more debris compared to the manual dynamic irrigation technique and none of the techniques completely removes debris from an isthmus [33]. Some *in vitro* studies have shown that none of the isthmuses in the root canals can be completely obturated with root-filling materials during conventional endodontic treatment [34,35]. It was shown that the production of dentinal debris during canal instrumentation and its penetration into the isthmuses of mesial root canals of mandibular molars prevent penetration of sealers and filling materials into the isthmuses despite continuous irrigation during and after instrumentation [35]. The prognosis of the root canal treatment can be predicted with this information.

A recent study by de Groot *et al.* (2009) [36] on the cleaning efficacy of laser-activated irrigation of root canals showed that this technique is more efficient in removing debris from the apical third of the root canal compared to passive ultrasonic irrigation and hand irrigation techniques. Therefore, proper management of isthmuses, including bacterial reduction and complete filling, requires future application of newer technologies and further studies to verify their efficacies.

However, CBCT has some limitations in detecting the root canal. It may be unable to show the details of the root canal system in cases where the canal is very small. MM canal is located in the sub-pulpal groove, and the canal is an additional canal that is usually smaller than the main canal. The canal may be smaller than the setting of the voxel size and, therefore, may not be detected in the image. This may affect the Presence of the MM canal in this study using CBCT images. Furthermore, CBCT is not used routinely in all cases of endodontic treatment and is considered only when further radiographic details are required for diagnosis and treatment planning.

Hence, any tooth indicated for root canal treatment should be treated with precaution. Technological advances should be used in disinfecting the enigmatic pulp space; for example, laser-activated irrigation system, which has shown better disinfection of the isthmus.

5. Conclusion

MM canals, according to the strict classification, were very rare, about 4.5% in a subpopulation of Andhra Pradesh. The clinician should be aware of the complexity of the mesial root of a mandibular Molar with the isthmus or fin between the main MB and ML canals. Isthmuses are very common in the mesial roots of permanent mandibular molars in the subpopulation of Andhra Pradesh. Isthmus, about 30.3%, was seen with Type II configuration that is the Presence of two canals without definite communication. Therefore, Dental operating microscopes and newer technologies should be used for cleaning and obturation of isthmuses to achieve higher success rates in endodontic treatment.

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