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REVIEW ARTICLE

Middle mesial canal in mandibular first molar: A narrative review

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Mandibular first molar (M1M);
Middle mesial canal (MMC)

Abstract *Purpose:* This review aimed to assess the incidence, anatomical characteristics, identification, and clinical management using conventional techniques and advanced tools to manage MMCs successfully.

Methods: Medline/PubMed and Scopus databases were searched using "Middle mesial canal," "Middle mesial root canal," OR "Accessory mesial canal" keywords from 1 January 1970 and 1 February 2023. The most pertinent articles were chosen for the review from the retrieved articles. In addition, relevant articles were added by manually searching the list of references.

Results: The incidence of MMC is noticeable in younger people, and the confluent canal is the most common type. The majority of MMCs merged with mesiobuccal (MB) canals rather than mesiolingual (ML) canals. Clinical management could be employed using the standard endodontics protocol, and recent radiography technologies, magnification, rotary, and obturation materials can facilitate the procedures.

Conclusion: The possibility of the incidence of MMC is not unusual. Detection and thorough debridement followed by obturation of the canal could increase the success rate of clinical outcomes.

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Contents

1. Introduction

Root canal therapy aims to locate all canal orifices, chemomechanically debriding the root canals to minimize the bacterial load and create the shape and space for the obturation with an inert material three-dimensionally to prevent the chances of reinfections (Vertucci, 2005). Obtaining clean root canals by adequate shaping is essential; however, overly enlarging the root canals with rotary files should be avoided, as this reduces the tooth's fracture resistance. (Gambarini et al., 2020; Lin et al., 2022).

Initial studies by Hess and Zurcher showed that the anatomy of the root canals is erratic and complex. The root canals might consist of multiple foramina, isthmus, fins, apical deltas, intercanal connections, loops, and accessory canals (Karobari et al., 2022). Although the anatomy is indeed complex, a low radiation dose and a wide field-of-view (FOV) of the Cone Beam Computed Tomography (CBCT) allows the operator to obtain the canal anatomy for proper treatment planning, simplifying decisions, reducing time, and aiding in the early detection of potential complications and operational difficulties, thereby enhancing treatment outcomes (Reda et al., 2022).

The M1M is the most common endodontically treated tooth (Reyhani et al., 2007), and usually, M1M has mesial and distal roots. Typically, the mesial root displayed two canals, the mesiobuccal (MB) and the mesiolingual (ML) canals, each of which terminates in a separate foramen (90 %). However, 10 % of cases merge near the foramen. The distal root consists of only one large canal (65 %) with an oval or kidney shape or two canals (35 %) (Ballullaya et al., 2013; Calberson et al., 2007).

M1M exhibits a range of anatomical variations, which include: MMC, Middle distal canal (MDC), Isthmus, Radix Paramolaris, Radix Entomolaris, and Taurodontism. The clinician should comprehensively understand these possible anatomic variations before attempting endodontic therapy to treat them successfully (Srivastava et al., 2018).

The present review emphasizes the incidence, anatomical characteristics, identification, and clinical management using conventional techniques and advanced tools to manage MMCs pertaining to M1M alone successfully.

2. Methods

PubMed/ Medline and Scopus databases were searched using the keywords "Middle mesial canal," "Middle mesial root canal," OR "Accessory mesial canal." Inclusion in the analysis was restricted to the articles published between 1 January 1970 and 1 February 2023 in English-language. Additional studies were included by manually searching the references of the most pertinent published original research, systematic reviews, review articles, case series, and reports.

3. Results:

3.1. MMCS: Incidence, Prevalence, and distribution

The prevalence of the MMCs varies according to ethnicity and ranges from 0.26 to 45.8 % (Pertek Hatipoğlu et al., 2023; Bansal et al., 2018). The incidence of MMC was initially stated in 1974 (Barker et al., 1974; Vertucci & Williams, 1974). Furthermore, a detailed study identifying the incidence and the clinical detection of MMC was reported (Pomeranz et al., 1981).

The accessory canals are formed due to the apposition of the secondary dentin that occurs throughout tooth development resulting in a vertical partition in the root (Srivastava et al., 2018). MMC is ubiquitous among younger to middle-aged patients and significantly more prevalent among younger patients. (Azim et al., 2015, Nosrat et al., 2015). In M1M, the incidence of MMCs on the left and right sides or between genders was insignificant. Moreover, MMCs exhibited a bilateral incidence (Pertek Hatipoğlu et al., 2023). The likelihood of identifying these small accessory canals decreases with age because continued secondary dentin formation causes obliteration, making it exceedingly difficult to identify and locate (Solomonov et al., 2020).

3.2. Location of MMC in relation to MB and ML canals

The MMC orifice may be located closer to ML or MB canal or equidistant from MB and ML canals. The majority of the previous studies and case reports showed that the orifice of the MMC is present closer to the ML canal than to the MB canal, followed by the incidence of the orifice between the two main canals, while the presence of the orifice near that of the MB canal is quite unusual (Karapinar-Kazandag et al., 2010; Nosrat et al., 2015; Pomeranz et al., 1981; Sherwani et al., 2016).

Karapinar-kazandag et al. (2010) found that about 45 % of the accessory mesial canals are close to the ML canal, whereas 30 % are at the center between MB and ML canals. Approximately 25 % are closer to the MB canal. Sherwani et al. (2016) observed that in about 67 % of the North Indian population, the orifices of the MMCs were present at the center of MB and ML canals. About 20.5 % of cases showed the orifice close to the ML canal, and 12.3 % had the orifices close to the MB canal. Deepalakshmi et al. (2012) reported MMC orifice is present at equidistant from the two main canals.

3.3. Distance between MB and ML orifices

Karapinar- Kazandag et al. (2010) reported that if the accessory mesial canal is closer to MB or ML, the distance between them is about 3.21 mm. Akbarzadeh et al. (2017) concluded that the average distance between MB and ML canal is about 3.1 mm in the roots with MMC, whereas the tooth without MMC showed an inter-orifice mean distance of about 3.7 mm. Weinberg et al. (2020) reported an inter-orifice distance of about 3.6 mm in the roots with MMC and 3.8 mm without MMC.

The incidence of the MMC was inversely associated with the MB-ML orifice distance; mainly, for every rise in 1 mm of inter-orifice distance, the chances of identification of MMC dropped by a factor of 2 times (Karapinar-Kazandag et al., 2010; Akbarzadeh et al., 2017; Weinberg et al., 2020).

3.4. Classification of MMCs

The MMCs were classified by Pomeranz et al. (1981) into (i) Fin type: an isthmus exists between the MMC and an MB or ML canal during any stage of course from the orifice to the apex, or an instrument can pass between MMC and MB or ML canal easily, as the orifices will merge after the instrumentation., (ii) Confluent type: Emerges as a separate orifice and joins with either MB or ML canal, through the transverse anastomosis, intercanal connections or isthmus during its course to the apical foramen and (iii) Independent type: Three separate canals from the pulp chamber to the apex.

Azim et al. (2015) reported a high incidence of confluent type (78.5 %) of MMC, followed by fin-type (12 %) and independent type (9.5 %). Nosrat et al. (2015) reported that about 46.7 % of the MMC are confluent type, 33.3 % are fin-type, and 20 % of the canals are independent. Karapinar- Kazandag et al. (2010) demonstrated that all MMCs were confluent, with no canal terminating as fin or independent type. Sherwani et al. (2016) reported a high incidence of confluent (75.3 %) anatomy, followed by fin-type (21.9 % and independent (2.7 %) type is uncommon.

The Confluent type is most common where the MMC joined either of the two main root canals (MB or ML). About 42 % of the MMC merged with the MB canal, followed by the ML canal (29 %) (Karapinar-Kazandag et al., 2010). According to Fabra-Campos, (1989), about 1.7 % of MMC merged with the MB canal, mainly in the apical thirds of the root canal. 1.6 % merged with ML canals. Versiani et al. (2016) demonstrated that about 20.8 % of the MMC joined the MB canal, and 16.7 % joined to ML canal.

3.5. Isthmus and its relation with MMCs

An isthmus is a narrow ribbon-like extension between the two main canals, which consists of pulp or pulpal-derived tissue (Cambruzzi & Marshall, 1983). A continuous association between the two main root canals is called the complete isthmus, while a partial isthmus is an incomplete connection between the main root canals (Weller et al., 1995). The isthmus was classified by Hsu and Kim (1997) into five different types as follows;

Type I: No communication between two or more canals.

Type II: Complete isthmus between two canals.

Type III: Three canals joined by a complete connection between them.

Type IV: Canals are found in the isthmus area. It consists of two elongated canals that communicate in the center.

Type V: The canal is single, elongated, and very broad.

The incidence of the complete or incomplete isthmus in the mesial root of the M1M ranges from 36 % to 83 %. Studies showed that the isthmus is frequently detected at 3–5 mm from the root apex. The presence of an incomplete isthmus is commonly encountered compared to a complete isthmus. However, the tooth may vary due to age, sex, and geographic distribution (Haghanifar et al., 2017; Hsu & Kim,1997; Teixeira et al., 2003).

MMC is most frequently detected in the tooth with an isthmus. An isthmus may augment the incidence of MMC. MMCs were identified nearly five times more frequently in M1M with an isthmus between two MB and ML canals (Akbarzadeh et al., 2017; Nosrat et al., 2015).

3.6. Mean diameter and volume of MMCs

The mean diameter of the major and minor constriction and the volume of the MMC is always smaller than the two main root canals (MB and ML). The minor diameter of MMCs with three independent canals was measured and found to be 0.16 mm and 0.40 mm for major diameters in Brazilian and Turkish populations. The volume of the MMC in the case of teeth with three independent canals was found to be 0.20 ± 0.10. The overall observations conclude that the mean diameter and volume of MMCs are 2–3 times lesser than the main canals (Versiani et al., 2016).

3.7. Curvature of the MMCs

The curvature of the MMC is considered age-dependent. The MMC exhibited moderate to severe curvature, whereas most MMCs showed a curvature starting from the middle thirds of the root canals. The curvature was very prominent towards the mesiodistal and buccolingual direction. However, the mesiodistal curvature of root canals decreased with age due to calcification (Yang et al., 2020).

3.8. Association between MMC and the presence of a second distal canal

It was reported that MMC is more common in M1M, having two distal canals (45.4 %) than those with one distal canal (Sherwani et al., 2016). However, Nosrat et al. (2015) found no correlation between MMC and the occurrence of the second distal canal.

3.9. Methods to identify MMCs: Technology-Based Methods

3.9.1. Radiographic method

A high-quality preoperative periapical conventional or digital radiograph is mandatory before the endodontic procedure. The paralleling cone technique is preferred for endodontic radiographs because it produces minimal distortion and nearly no overlap with bony structures. At least two preoperative radiographs with varying horizontal angulations must be performed, determining the roots' buccolingual width which suggests the existence of accessory canals (Setzer & Lee, 2021).

The occurrence of extra roots and canals is more probable: i) If the root tip is more bulbous, ii) If the canal abruptly disappears (Breakpoint), iii) If the placement of the lesion is eccentric, iv) If the Periodontal ligament is enlarged in the middle of the root, v) If the file is not in the centre of the root (Ahmed, 2015).

3.9.2. Cone-Beam Computed Tomography (CBCT)

Cone-beam computed tomography (CBCT) is an advanced imaging modality for examining hard tissues in the dental and maxillofacial regions. CBCT produces a high-quality image and interprets it in three-dimensional views, making it more useful in endodontics. CBCT uses a cone or pyramidal-shaped beam of radiation to acquire a volume in a single partial (≥180) or full 360-degree rotation (Oser et al., 2017).

The American Academy of Oral and Maxillofacial Radiology and the American Association of Endodontists published a joint position statement in 2015 that CBCT imaging must not be utilized routinely for endodontic diagnosis or screening purposes, especially in the lack of clinical signs and symptoms. However, the case selection criteria for using CBCT imaging for endodontic applications could be more precise and specific (Fayad et al., 2015). CBCT scanned images guide the clinician to the correct location, angle, and depth to access the patent portion of the canals found and correctly treated.

A recent report stated that seven distinct MMCs were detected clinically and on CBCT images with an incidence rate of 13.725 %. Many teeth had a broad isthmus between the MB and ML canal orifices on the CBCT images (Weinberg et al., 2020). Out of 122 scans examined, 22.22 % had MMC; 15.56 % were female, and 6.66 % were male. Interestingly, the prevalence of the MMC was 11.47 % in M1Ms. (Arashlow et al., 2017).

In some cases, MMCs were located at the furcation area but merged with the MB or ML canal toward the apex in two-thirds of these cases (Keles & Keskin, 2018).

CBCT detectors are reported to improve and increase image quality, contrast, and spatial resolution, reducing noise and image artifacts. Pertek Hatipoğlu et al. (2023) suggested using a small FOV ranging from 6x8 to 15x15 cm and a voxel size ranging from 100 to 200 μm to obtain higher-quality images that depict the presence of MMCs more accurately. The limited FOV results in a higher spatial resolution and a lower radiation dose with shorter volumes to be interpreted.

3.9.3. Dental operating microscope (DOM)

The dental operating microscope (DOM) is used in endodontics to assist with various treatment procedures (Low et al., 2018). A 2.5–10 X magnification is routinely preferred to perform most steps during the root canal treatment. In contrast, complex procedures like instrument retrieval, bypassing a ledge, apical surgery, etc., might require a higher magnification.

The DOM has substantially increased the probability of locating the MMC. It has been demonstrated that a preoperative CBCT scan to obtain a better idea about the internal anatomy, followed by adequate de-roofing of the pulp chamber by selectively troughing under a microscope, increases the likelihood of finding these additional canals while preserving the tooth structure (Scarfe et al., 2009).

3.10. Clinical Methods to detect MMCs

3.10.1. Adequate access cavity preparation and Red Line Test

The access cavity should be prepared by following all the laws of Krasner and Rankow. The access cavity preparation should allow a better vision of the pulpal floor and improved diagnostic and straight-line access to the orifices (Adams & Tomson, 2014). The standard errors while preparing the access cavities, such as; incomplete removal of caries from the pulp chamber, incomplete deroofing of the pulp chamber, over preparation, or perforations, reduce the chances of locating accessory and main canals. In cases where the pulp is vital, bleeding points can be observed on the pulp chamber floor, suggesting root canal orifices. In a few cases, blood regularly moves into an isthmus area. It absorbs into orifices, fins, and isthmuses, which serve as a roadmap to aid in recognizing the underlying anatomy referred to as the Red Line Test (Gandhi et al., 2012).

3.10.2. Exploration and negotiation of MMCs

The orifices of MMC can be located by carefully exploring the pulp chamber floor using a sharp endodontic explorer (DG 16), a small stiff stainless steel K-file, or Micro-openers (Patel & Rhodes, 2007). After a proper access opening, a sharp endodontic explorer should be passed through the groove between the MB and ML canals. Careful probing of this area may encounter a "catch" or a "stick" feeling, which confirms the presence of an accessory canal (Subbiya et al., 2013).

A small number of rigid stainless steel K-files, preferably a 6, 8, or 10 no file, can also be used to explore and negotiate these narrow canals carefully. The canal can be negotiated using a slow-watch winding motion until it reaches the apex by placing an adequate volume of sodium hypochlorite within the pulp chamber (Van der Vyver et al., 2020).

The micro-openers are flexible ISO-sized hand instruments with 7 mm K-type flutes mounted to a handle. The unrealistic taper improves the instrument's tensile strength and is specially designed to use with magnification (Gandhi et al., 2012; Siddiqui & Mohamed, 2016).

3.10.3. Guided troughing technique

Dentinal protuberance within the mesial canals makes locating and negotiating MMC challenging. The guided troughing technique could increase the chances of finding MMC. A small-headed Munce discovery bur (#2) or ultrasonic tips are most commonly used for troughing (Karapinar-Kazandag et al., 2010; Prade et al., 2019).

Most MMC orifices are located close to the ML canal, so the clinician should search by troughing from the ML canal and slowly progressing within the groove close to the MB canal (Karapinar-Kazandag et al., 2010). The troughing should be done in an apical direction at the expense of the mesial–axial wall away from the furcation area (danger zone) to avoid the chances of strip perforation, as the thickness of the dentin is less than 1 mm in this area (Azim et al., 2015; De-Deus et al., 2019).

The mean depth of the dentin should be removed is about 0.7–2 mm (Azim et al., 2015; Karapinar-Kazandag et al., 2010; Prade et al., 2019). According to Keles and Keskin (2017), 77.41 % of MMC were discovered without troughing since most of the orifices of these accessory canals are located at the cementoenamel junction. In contrast, few cases required cautious troughing to detect root canal orifices.

While troughing with ultrasonic tips, the pulp chamber floor should be frequently inspected for grooves packed with dentin chips. This helps in the identification of hidden orifices (White Line Test). Troughing should be carried out under magnification to prevent the unnecessary removal of the tooth structure and also helps identify the root canal orifices (Gopal et al., 2014).

3.10.4. Champagne bubble Test

The access cavity should be prepared adequately, and later the pulp chamber should be filled with 3–5.25 % sodium hypochlorite to check for accessory canals after locating the major canals. If the accessory canals are present, the irrigant will react with pulpal tissue within the orifice of the tooth and release a stream of bubbles due to the oxygenation of the pulp tissue. The operator should observe the pulp chamber under a DOM to identify and locate the origin of the bubbles. The area from where the bubbles originate indicates the presence of a canal orifice (McCabe & Dummer, 2012; Nair et al., 2019).

3.10.5. Methylene blue dye Test

The 1 % methylene blue is the most frequently used dye to locate the canal orifice. It can be applied into the pulp chambers and then rinsed thoroughly with water, dried, and visualized. The dye will be absorbed into the orifices, which helps identify the root canal orifices and is referred to as a Dye test (Mohammadi et al., 2016).

3.11. Cleaning and shaping of MMCs

Most MMCs are narrow, tortuous, curved, or joined to one of the primary root canals; therefore, these canals must be cleaned and shaped meticulously to avoid procedural errors (de Mattos et al., 2022). A proper glide path preparation, the right selection of rotary files, and a proper technique would efficiently clean and shape without procedural errors (Ajina et al., 2022; Chaniotis & Ordinola-Zapata, 2022; Patil et al., 2017).

K-files with a high buckling resistance or C + files can negotiate the canals efficiently without bending since they are rigid and easily progress through a narrow, tortuous canal (Martins et al., 2022). The files should always be used in the presence of sodium hypochlorite, and a watch-winding technique should facilitate the file's movement within the root canal system (Yared, 2015). The canals should be enlarged adequately to a # 10 K-file before using a rotary file for the glide path preparation (Arias & Peters, 2022; Neelakantan et al., 2022). Compared to K-files, rotary glide path files can prepare canals more efficiently (Htun et al., 2020). If the clinician prefers to prepare a glide path using K-files, using intermediate files, such as # 12 and 17, is more beneficial for achieving a smoother transition between the files and aids in easier penetration through canal constrictions (Plotino et al., 2020).

It is always preferable to utilize constant taper rotary files that have been heat-treated while instrumenting the MMCs (Kılıç et al., 2021). The apical enlargement should be done considering the configuration of the MMCs. Since the diameter of the apical constriction in these canals is minor. Preparing these canals to smaller sizes with less taper, preferably 4 %, is always better. The apical enlargement is decided by using the technique of apical gauging (Weller et al.,1995; Zhou et al., 2022).

The crown-down instrumentation technique is preferred for cleaning and shaping these accessory canals, and care must be taken during instrumentation (Puleio et al., 2022). A careful brushing motion is employed away from the furcation area and toward the mesial side of the root. MMCs generally exhibit moderate to severe three-dimensional curvature, with the curvature beginning at any point within the canal. Understanding the shape and curvature of the root canal in advance might enhance the success rate of root canal therapy (Yang et al., 2020).

For irrigation, syringe irrigation can effectively clean the main root canals but cannot clean the root canal abbreviations and anatomic irregularities that are common in the case of MMC. Supplementary irrigation techniques such as sonic, passive ultrasonic, and negative apical pressure should be used to obtain clean canals. These techniques resulted in better debris removal than conventional techniques (de Mattos et al., 2022; Kumar et al., 2023). Recent developments in equipment based on the concept of Photoactivated disinfection, photon-induced photoacoustic streaming, gentle wave system, etc., are significant milestones in the irrigation of root canals. These irrigating systems provide adequate tissue dissolving and debris removal from the anastomoses and significantly reduce the bacterial load within the root canal system (Kishen et al., 2016; Boutsioukis & Arias-Moliz, 2022).

3.12. Obturation of MMCs

Root canal therapy aims to adequately seal the root canal system and prevent reinfection of the root canal (Li et al., 2014). Different obturation techniques can be employed to obturate the MMCs. The obturation technique depends on operator skills, root canal configuration, and materials and equipment availability. The MMCs were obturated employing cold lateral compaction of gutta-percha cones in the apical third, subsequently vertically compacted of thermoplasticized gutta-percha (Nosrat et al., 2015; Sivaramakrishnan et al., 2020).

The MMC could be separated or confluent with main mesial canals, and obturation was done successfully using laterally condensed gutta-percha cones in combination with a different sealer (Baugh & Wallace, 2004; La et al., 2010). In another case report, obturation was performed utilizing a warm vertical compacted gutta-percha and AH Plus sealer (Jabali, 2018).

4. Conclusion

Due to the rapid advancement of technologies like CBCT and DOM, the likelihood of identifying and locating MMCs in M1M has increased. Detection of these canals, followed by careful and proper cleaning and shaping to obturation, improves the outcome of root canal treatment. Young individuals with a complete isthmus connecting the two major canals are likelier to have MMCs. Most often observed is the confluent canal, in which the MMC merges with the MB canal. The MMC is located between the MB and ML canals, while the distance between the MMC and the main canal can vary. These MMCs are narrow, with a mean diameter being minor. The canals displayed significant curvature. Understanding the above characteristics is essential for any practitioner treating a tooth with MMCs.

CRediT authorship contribution statement

Raghavendra Penukonda: Conceptualization, Writing – original draft, Writing – review & editing. **Harshada Pattar:** Data curation, Writing – original draft. **Phrabhakaran Nambiar:** Supervision. **Afaf Al-Haddad:** Investigation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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