Middle Mesial Canal Identification and Endodontic Management of the Mandibular First Molar with Five Canals: A Case Report

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ABSTRACT

Introduction: The middle mesial canal (MMC) is an anatomical variation occasionally encountered in mandibular first molars and often overlooked during endodontic treatment, potentially compromising clinical outcomes. This case report underscores the importance of recognizing and managing an MMC in five-canals mandibular molar. **Methods:** A 16-year-old male presented with lingering pain in the lower right posterior region. Clinical and radiographic findings led to a diagnosis of symptomatic irreversible pulpitis with symptomatic apical periodontitis in tooth #46. Canal exploration employed SLOB radiographic technique, magnification, ultrasonic troughing, and application of Krasner and Rankow's laws. Five canal orifices were located—three in the mesial root, including a middle mesial canal, and two in the distal root. Canal preparation was achieved using Reciproc Blue instruments, coupled with passive ultrasonic irrigation for enhanced debridement. Obturation was performed with gutta-percha and a bioceramic sealer, chosen for its superior flowability and bioactivity. A full-coverage indirect overlay was placed to reinforce the remaining tooth structure. **Results:** At one-month follow-up, the patient reported complete resolution of symptoms, with radiographs showing well-obturated canals, intact periapical structures, and a functional restoration. **Discussion:** The presence of an MMC demands meticulous assessment and advanced visualization techniques. Knowledge of pulpal anatomy, effective instrumentation, and appropriate restorative choices are essential for long-term success. **Conclusion**: Successful endodontic outcomes depend on comprehensive canal identification, effective disinfection and obturation, and appropriate post-endodontic restoration

Keywords

Middle Mesial Canal, Mandibular First Molar, Five Canals, Endodontic Management, Canal Identification

INTRODUCTION

Mandibular molars are the most common teeth to undergo endodontic therapy. They typically present with two canals in the mesial root and one or two canals in the distal root.[1] The internal anatomy of the mandibular first molar exhibits several variations such as an additional distolingual or mesiobuccal root, C-shaped root canal system, and isthmuses connecting the canals. For example, an additional canal or variations within the canal system can complicate the cleaning and shaping procedure and may require careful examination to detect. Additionally, a third canal may occasionally be identified in the isthmus between the mesiobuccal (MB) and mesiolingual (ML) canals, referred to as the middle mesial canal (MMC).[2,3] Recognizing these anatomical variations is crucial for successful root canal treatment. Missing a canal or failing to address a complex root system can lead to treatment failure.[4]

The middle mesial canal (MMC), also known as "accessory mesial canal," or "mesiocentral canal," is formed by the apposition of secondary dentin during tooth development, which creates a vertical wall inside the root.[5] The occurrence of MMC varies among populations and tooth types.[6] For example, Vertucci and Williams (1974) and Barker et al (1974) were the first to verify its independent presence of the MMC in mandibular molars, reporting frequencies ranging from 10.8% to 27% across different ethnic groups and age ranges.[7] Additional research has shown that prevalence of MMCs depends ethnicity and can range from 0.26 to 45.8 %. Various studies have reported that the incidence of a middle mesial canal (MMC) in the mesial root ranges from 10-37,5 % in first mandibular molars and 18–60% in the second mandibular molars.[3,6] MMCs are more commonly observed in younger to middle-aged individuals, with a notably higher prevalence among younger patients. As age increases, the probability of detecting these small accessory canals decreases due to the progressive secondary dentin deposition, which can lead to canal obliteration and increased difficulty in identification.[8,9] Understanding these prevalence rates and age-related changes is crucial for clinicians to ensure thorough canal exploration during endodontic treatment, particularly in younger patients where MMCs are more likely to be present.

Pomeranz et al. (1981) classified MMC into three types: 1. Fin type: An isthmus exists between the MMC and MB or ML canals at any stage, allowing easy passage of instruments. The orifices often merge after instrumentation. 2. Confluent type: This starts as a separate orifice and joins MB or ML canals via connections or isthmuses before reaching the apex. 3. Independent type: Three separate canals extend from the pulp chamber to the apex. MMC is most often found in teeth that have an isthmus, which may explain its increased occurrence in certain cases, particularly those corresponding to the fin and confluent types described above. [9–11]

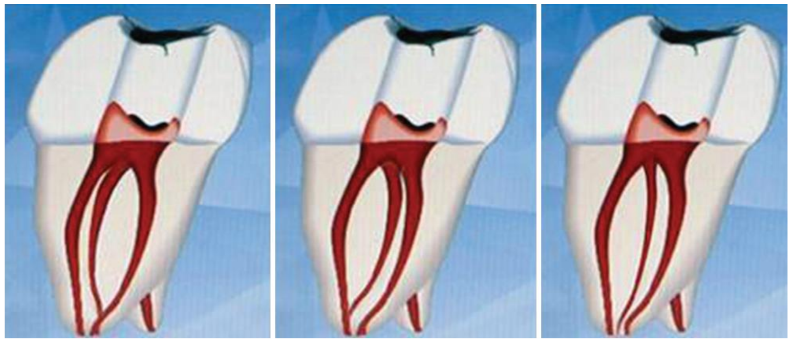

Figure 1. Pomeranz et al. classification of middle mesial canal. (a) and (b) are classified as confluent where MMC joins Mesiolingual and Mesiobuccal respectively. (c) Represents independent MMC.[11]

Accurate identification of all topographic locations of additional canal orifices is essential for clinicians.[12] This process generally consists of four stages: (1) pre-access analysis, (2) removal of the pulp chamber roof, (3) identification the pulp chamber floor and canal orifices, and (4) instrumentation of the root canals. Among these, the detection of MMC may be facilitate through various methods, including digital radiography at different angulations (SLOB technique), diagnostic aids such as dyes, the champagne bubble test, DG-16 explorer, micro-openers and careful inspection of bleeding points within the chamber.[6,13,14] Adequate access cavity preparation that adheres to the laws of Krasner and Rankow provide improved visualization of the pulpal floor, enhanced diagnostic accuracy, and more predictable straight-line access to the canal orifices.[10,14] Furthermore, ultrasonic troughing, when performed under magnification devices such as magnifying loupes or dental operating microscopes, minimizes procedural errors and increases the likelihood of locating additional canals. Ultimately, a properly prepared access cavity facilitates thorough irrigation, effective cleaning and shaping, and high-quality obturation of the root canal system.[13–15]

Endodontic therapy consists of three fundamental steps: biomechanical preparation, microbial control, and complete obturation of the root canal system to facilitate periapical healing. Cleaning and shaping of the pulpa complex should enable effective pulp tissue removal and adequate canal access, while preserving the integrity of coronal enamel and dentin. [16,17] The long-term prognosis of root-filled teeth, however, depends not only on the quality of the endodontic treatment but also on the amount of remaining dentine and the type of final restoration.[18] Following the obturation phase, a comprehensive restorative plan must be implemented to re-establish the tooth’s functional role within the oral cavity. Therefore, clinicians should approach each procedure with a clear perspective on the final post endodontic restoration.

Endodontically treated teeth are more susceptible to fractures due to the loss of natural tooth structure and the inherent structural compromises associated with the treatment itself.[19] Research has shown that fiber-reinforced composites enhance the ability of these teeth to withstand fractures by improving stress distribution and supporting the remaining dentin, thereby reducing the risk of catastrophic failure.[20,21] Furthermore, it is essential to consider that cuspal coverage may be performed in most endodontically treated teeth, following the minimally invasive procedures to reduce the risk for fracture and improve the prognosis of these teeth.[22] Among available restorative options, lithium disilicate adhesive overlays are considered preferable when adequate dental tissue remains and no pre-existing crown is present, offering superior esthetics, high flexural strength, and conservative preservation of the natural tooth.[23,24]

This case report aims to emphasize the paramount importance of identifying the middle mesial canal, following by thorough cleaning, shaping, and filling of all root canals to achieve favorable treatment outcomes. The procedural phase describes focuses on the endodontic management of a mandibular first molar with five canals. This includes accurate localization of all canal orifices, meticulous shaping and disinfection, and complete obturation of the canals, while preserving the remaining tooth structure. Subsequently, an appropriate post-endodontic restoration is performed to ensure long-term functional stability and aesthetic integrity.

CASE REPORT

A 16-year-old male with a chief complaint of decayed tooth with lingering pain in the lower right posterior region for the past two weeks. The pain increased on taking cold foods and at night. Intraoral examination revealed deep class I carious lesion associated with tooth number #46 (Figure 2A). The tooth was non-mobile with tenderness on percussion. Pulp vitality test result is prolonged lingering pain to cold stimulus and electric pulp testing the tooth gave positive response. The preoperative diagnostic radiograph revealed a deep carious lesion occlusally involving the pulp along with widening of periodontal space apically (Figure 2B). However, no abnormalities are observed at the alveolar crest and periapical area. Based upon clinical and radiographic findings, according to the diagnostic criteria of the American Association of Endodontists (AAE), the diagnosis for this case is a diagnosis symptomatic irreversible pulpitis, symptomatic apical periodontitis. Treatment plan was explained to the patient and informed consent was obtained. Endodontic treatment was started in the multiple visits.

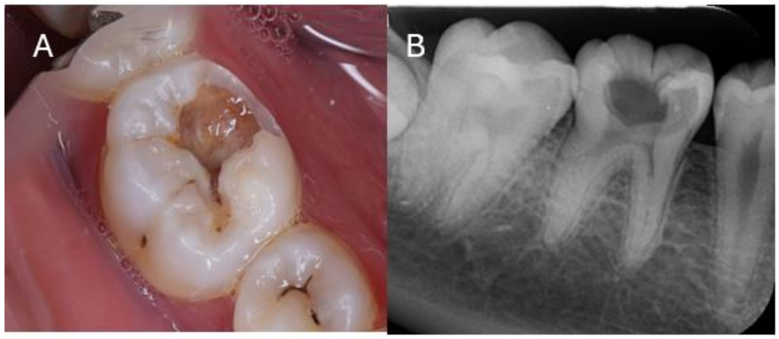

Figure 2. (A) Intraoral preoperative photograph of tooth 46 showing deep class I carious lesion. (B)Preoperative periapical radiograph showing deep carious lesion involving the pulp with widening of periodontal space apically

After administration of local anaesthesia and isolation with rubber dam, access cavity was prepared using a diamond bur and an endodontic access bur (Dentsply Sirona, North Carolina, USA). Initial access revealed two mesial canals and two distal canals (MB, ML, DB, DL) (Figure 3A). Under magnification with the loop 5x magnification, a developmental groove between MB and ML suggested an MMC, which was confirmed using DG-16 explorer (Hu-Friedy, Chicago, USA) and micro-opener (VDW, Munich, Germany) (Figure 3B). The MB, ML, DB, DL was negotiated using C-Pilot file #10 (VDW, Munich, Germany), whereas the MMC was negotiated using C-Pilot file #8 (VDW, Munich, Germany). The Working length was determined using an electronic apex locator (ProPex Pixi, Dentsply Sirona, North Carolina, USA) at the "0.0" reading, and the MMC was subsequently confirmed radiographically with the SLOB technique using a C-Pilot file #8 (VDW, Munich, Germany) (Figure 3C).

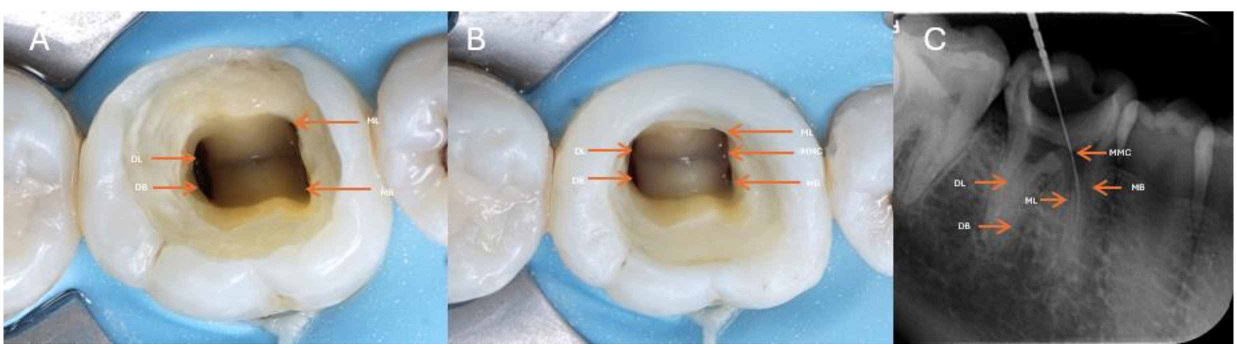

Figure 3. (A) Initial access revealed two mesial canals and two distal canals. (B) a developmental groove between MB and ML suggested an MMC, which was confirmed to be using DG-16 explorer (Hu-Friedy, Chicago, USA) and micro-opener (VDW, Munich, Germany). (C) MMC confirmed radiographically with SLOB technique using C-Pilot file #8

After glidepath and patency were achieved with a C-Pilot file #10 (VDW, Munchen, Germany), cleaning and shaping of all canals were performed using Niti rotary instruments with crown-down technique. All canals were prepared using the Reciproc Blue file (VDW, Munich, Germany), which has a regressive taper and is manufactured with blue heat-treated metallurgy. Instrumentation was carried out with a reciprocating motor (Woodpecker AI motor, Guilin, China) set at 300 rpm with reciprocating angles of 30°-150° (Figure 4A). The Reciproc Blue file was then introduced into the canal and advanced with a slow in-and-out pecking motion under light pressure until two-thirds of the estimated working length was reached. The instrument was removed from the canal after three pecking motions, the flutes were cleaned, and the canal was irrigated with 5,25% NaOCl (Figure 4B). Then working length was then precisely re-determined using a manual K-file #10 and an electronic apex locator (EAL), after which canal instrumentation was completed to the full working length. Copious irrigation was performed with 5,25% NaOCl, ultrasonically activated with the Endo Activator (Endo3, Woodpecker, Guilin, China) (Figure 4C), and 17% EDTA, interspersed with saline solution, was used to remove the smear layer during instrumentation.

All Canals were subsequently dried with paper points (Figure 4D) and an intracanal medicament of calcium hydroxide (Calcipex II, Nippon Shika Y) was placed for two weeks (Figure 4E). Finally, the access cavity was sealed with a temporary restorative material (Caviton, GC, Tokyo, Japan) to prevent coronal leakage until the subsequent appointment (Figure 4F).

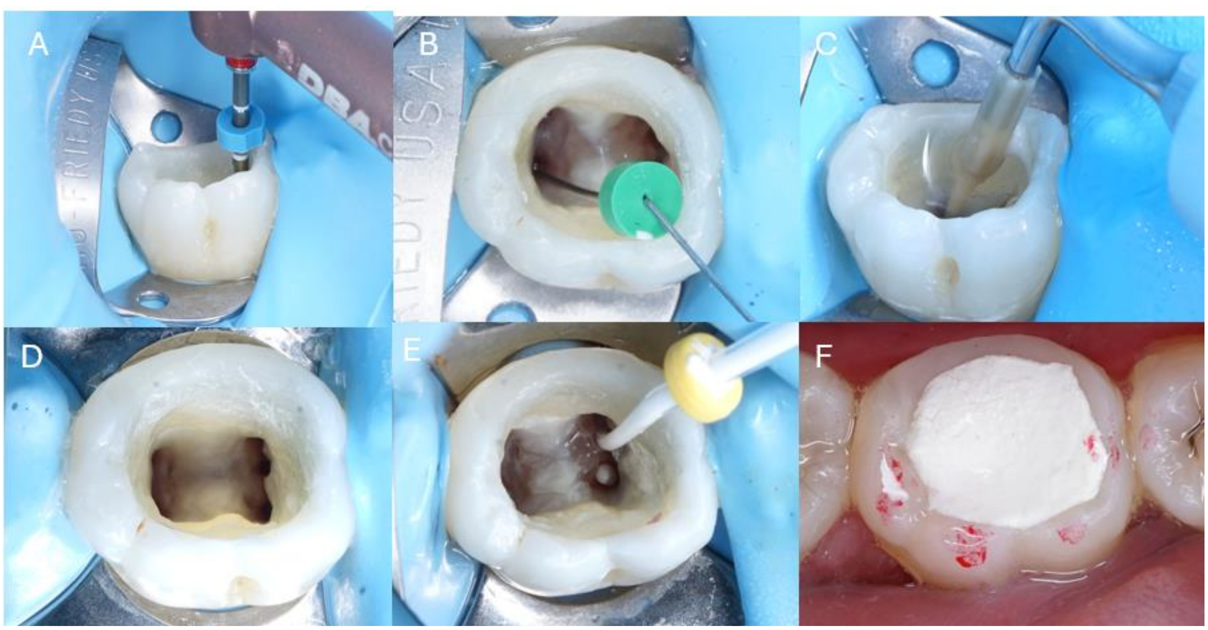

Figure 4. (A) All the canals were instrumented with Reciproc Blue File (VDW, Munich, Germany). (B) Copious irrigation was done with 5,25% sodium hypochlorite, 17% EDTA interspersed with saline solution during instrumentation. (C) Passive Ultrasonic Irrigation using Endo Activator (Endo3, Woodpecker, Guilin, China). (D) All canals were cleaned, shaped, and dried with paper points. (E) Calcium hydroxide (Calcipex II, Nippon Shika Y) was applied into the canals. (F) The access cavity was subsequently sealed using a temporary restorative material (Caviton, GC, Tokyo, Japan).

At the subsequent visit, both subjective and objective examinations revealed no abnormalities. A Reciproc Blue gutta-percha cone size 25 was fitted, and periapical radiographs using the SLOB technique were obtained to confirm proper adaptation to the root canal shape and working length (Figure 5A). After radiographic confirmation of the master cone fitting, a Reciproc Blue gutta-percha cone (VDW, Munich, Germany**)** coated with a bioceramic sealer (CeraSeal, Meta-Biomed, Korea) was carefully inserted into the prepared root canal system. Vertical condensation was then performed in the apical direction to achieve a dense and homogeneous fill, extending approximately 1–2 mm below the canal orifice, using a heated endo plugger (Figure 5B). A postoperative periapical radiograph was subsequently taken to verify the three-dimensional sealing of all canals, confirming adequate obturation without voids or overextension (Figure 5C). Finally, Smart Dentin Replacement (SDR, Dentsply Sirona, North Carolina, USA) was applied to the cavity floor (Figure 5D), and the access cavity was temporaly sealed with a provisional restorative material (Caviton, GC, Tokyo, Japan).

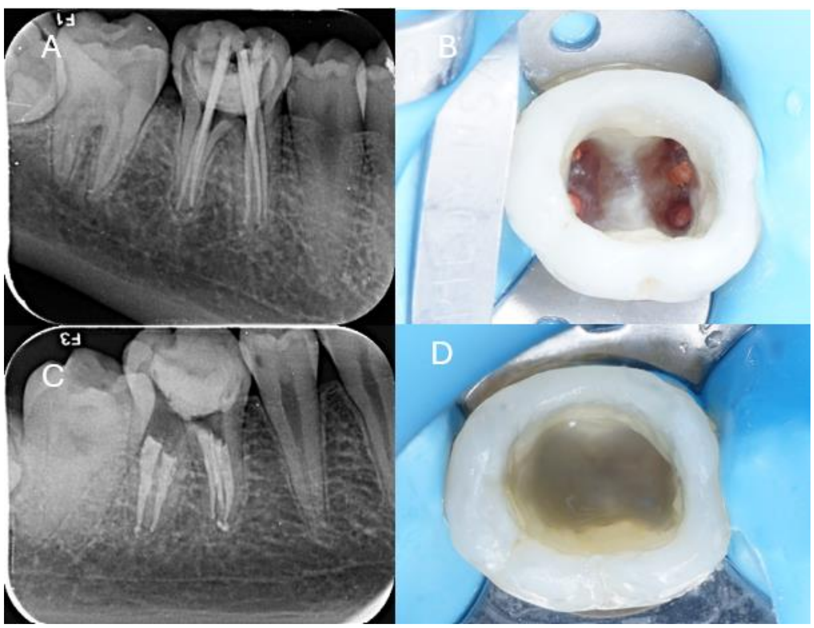

Figure 5. (A) Size 25 Reciproc gutta-percha cones were fitted, and periapical images using SLOB technique confirmed adaptation to the root canal shape and working length. (B) The cone was placed in the canal orifice, and vertical condensation toward the apex achieved a dense fill about 1–2 mm below the orifice using a heated endo plugger. (C) A postoperative periapical radiograph was obtained to assess the three-dimensional sealing of all canals, indicating obturation with no detected voids or overextension. (D) Smart Dentin Replacement (SDR, Dentsply Sirona, North Carolina, USA) was placed on the cavity floor.

On the third visit, both percussion and palpation tests revealed no abnormalities during subjective and objective examinations. Post-operative radiographic assessment demonstrated complete obturation of the root canal with no abnormalities in the periapical area (Figure 6A). After removal of the temporary restoration under rubber dam isolation, the cavity was disinfected with 2% chlorhexidine digluconate for one minute. Etching was then performed with 37% phosphoric acid, followed by the application of a universal adhesive system (Scotchbond Universal, 3M) in accordance with the manufacturer's instructions (Figure 6B and 6C). A core build-up was subsequently carried out using a short fiber-reinforced composite (EverX, GC,Tokyo, Japan) for dentin replacement, applied in horizontal increments of 1–1.5 mm and light-cured for 20 seconds each (Figure 6D). Packable composite resin (Enamel Plus HRi, Micerium S.p.A., Avegno, Italy) was then placed in 1–2 mm increments, each light-cured for 20 seconds with an LED curing light (Curing Light LED-C, Eighteeth Medical Technology Co., Ltd., Changzhou, China), to restore proper anatomy and occlusion (Figure 6E). Final occlusal adjustments were made using finishing bur, and polishing was completed with a polishing kit and spiral rubber discs (Diacomp, EVE Ernst Vetter GmbH, Germany) (Figure 6F).

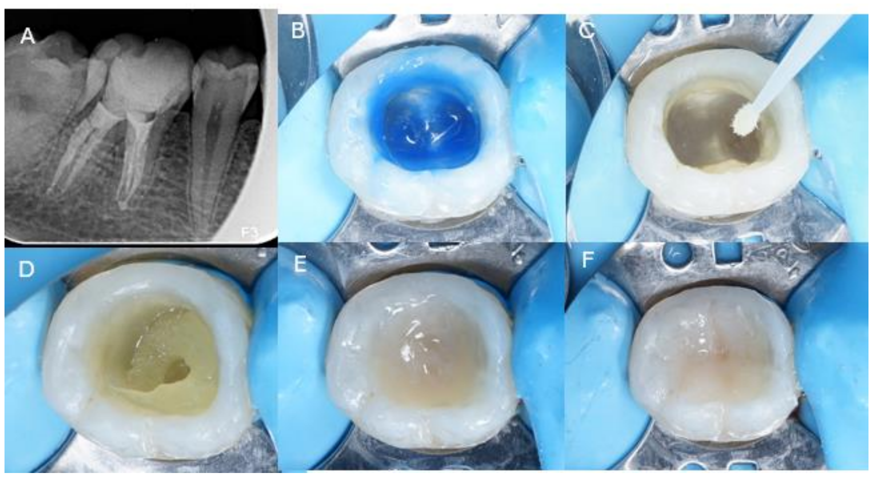

Figure 6. (A) During the third appointment, Postoperative radiographic evaluation demonstrated complete obturation of the root canal, with no abnormalities observed in the periapical region. (B)(C) Etching was carried out using 37% phosphoric acid, then a universal adhesive system (Scotchbond Universal, 3M) was applied in accordance with the manufacturer's guidelines. (D) A core build-up was subsequently performed utilizing a short fiber-reinforced composite (EverX, GC, Tokyo, Japan) to replace dentin. (E) Packable composite resin (Enamel Plus HRi, Micerium S.p.A., Avegno, Italy) was placed in 1–2 mm layers. (F) Proper anatomy and occlusion were achieved

After two weeks of symptom-free follow-up, the tooth was restored with a minimally invasive indirect overlay fabricated from lithium disilicate glass-ceramic (IPS e.max Press, Ivoclar Vivadent). Tooth preparation followed a morphologically driven overlay design, including a proximal box and partial lingual reduction to replace the caries-affected surfaces while preserving as much healthy tooth structure as possible (Figure 7A). A digital impression was obtained with intraoral scanner (Dentsply Sirona, North Carolina, USA) and subsequently processed for CAD/CAM design and overlay fabrication (Figure 7B and 7C). During the try-in appointment, the lithium disilicate restoration was evaluated for marginal fit, proximal contacts, and occlusal adaptation. Rubber dam isolation was applied, and the tooth surface was cleaned with particle-air abrasion to remove remnants of temporary cement.

The internal surface of the lithium disilicate restoration was etched with 9% hydrofluoric acid (Ultradent Porcelain Etch, Ultradent, Colone, Germany) for 90 seconds, rinsed, dried, and silanized with Ultradent Silane (Ultradent, Colone, Germany) for 60 second, following the manufacturer's instructions (Figure 7D and 7E). The prepared tooth surface was then etched with 37% phosphoric acid for 15 seconds, rinsed, and gently air-dried. A universal adhesive system (Scotchbond Universal, 3M) was applied using a scrubbing motion for 20 seconds, followed by air-thinning, without light curing (Figure 7F and 7G). The restoration was luted with a self-adhesive resin cement (3M™ Relyx™ U200, 3M, USA) (Figure 8H). Excess cement was carefully removed, and polymerization was completed using an LED curing light from multiple directions for 40 seconds each. Finally, occlusion was evaluated and found to be satisfactory, with no adjustments required.

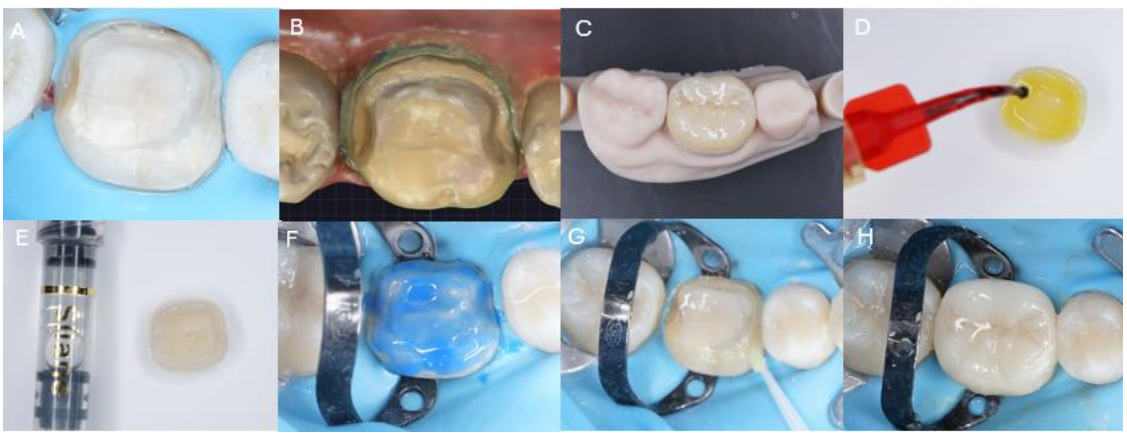

Figure 7. (A) The tooth was prepared with a morphologically guided overlay, featuring a proximal box and partial lingual reduction to restore caries-affected areas while conserving healthy structure. (B), (C) A digital impression was obtained using an intraoral scanner (Dentsply Sirona, North Carolina, USA), which was subsequently utilized for CAD/CAM design and overlay fabrication. (D), (E) The internal surface of the lithium disilicate restoration was treated with 9% hydrofluoric acid (Ultradent Porcelain Etch, Ultradent, Colone, Germany) for 90 seconds, then rinsed, dried, and silanized (Ultradent Silane, Ultradent, Colone, Germany) for 60 seconds. (F), (G) The tooth surface was etched with 37% phosphoric acid for 15 seconds, rinsed, and gently air-dried. Scotchbond Universal adhesive (3M) was then scrubbed on for 20 seconds and air-thinned, without light curing. (H) The restoration was subsequently luted with a self-adhesive resin cement (3M™ Relyx™ U200, 3M, USA), following removal of excess cement, polymerization was finalized using an LED curing light applied from multiple directions for 40 seconds each.

After cementation of the restoration, the patient was scheduled for a follow-up appointment two weeks later (Figure 8A and 8B). At this visit, the patient reported no complaints and expressed satisfaction with the treatment outcome. Both percussion and biting tests were negative, indicating the absence of gingival inflammation. A bitewing intraoral radiograph was obtained to evaluate the efficacy of the treatment (8C). The patient again expressed satisfaction and reported no discomfort. Finally, dental health education was provided to ensure the proper maintenance of oral hygiene.

Figure 8. (A), (B) After the restoration was cemented, the patient returned for a follow-up two weeks later. The patient reported no issues and was satisfied with the outcome. (C) A bitewing intraoral radiograph was taken to evaluate treatment efficacy.

FOLLOW UP

At the one-month follow-up, the patient reported no discomfort, and both clinical and radiographic examinations confirmed the success of the endodontic treatment and the adhesive indirect restoration. Percussion and palpation tests were negative, and the restoration exhibited excellent marginal integrity, functional stability, and esthetics. Radiographs evaluation confirmed intact obturation in all canals and the absence of periapical changes (Figure 9). The lithium disilicate overlay demonstrated excellent marginal adaptation and functional performance.

Figure 9.At one-month follow up, Clinical and radiographic exams confirmed successful endodontic treatment and adhesive indirect restoration, with no periapical changes.

DISCUSSION

Identification the middle mesial canal (MMC) is crucial, as missing a canal is one of the leading causes of endodontic failure. The use of magnification, illumination, and systematic exploration of the developmental groove significantly increase the likelihood of detecting MMC.[25] The trajectory of the MMC may present different morphological patterns.[10,25] It can be independent (Vertucci type I), with a separate entrance and foramen, or it may join another canal at the apical level (Vertucci Type II), a confluence that is more common with the mesiobucal canal. This canal is not always located in the median region, between the mesiobuccal canal and mesiolingual canals, and it may often be very close to the entrance of one of these canals.[10,12] Due to this proximity, many clinicians, including endodontist, may fail to identify it.[26] However, in this case, the MMC originated as a separate orifices and converged at the apical level (confluent type). Therefore, thorough knowledge of the internal anatomy of root canals is essential for successful treatment.

A high-quality preoperative periapical radiograph, either conventional or digital is mandatory prior to endodontic treatment. The SLOB technique is preferred in endodontic radiography when it is necessary to determine the buccolingual position of root canals, accessory canals, foreign objects, or periapical lesions, as it provides spatial information that cannot be obtained from a single radiograph. At least two preoperative radiographs with different horizontal angulations should be obtained to determine the buccolingual width of the roots, which may suggests the presence accessory canals.[10,27] Successful endodontic therapy depends on proper cleaning and complete instrumentation of all root canals; therefore, accurate identification of every canals is essential. In such situations, magnification becomes indispensable, whether through dental loupes or a dental operating microscope (DOM), to enhance the detection of canals. The combined use magnification and radiographs taken at different horizontal angulations, with instruments placed inside the canals, can further assist in canal identification.[26 28] For the identification and access of such canals, optimal illumination and high magnification are required.[28] For improved visualization, it is advisable to work under dry conditions initially, rinsing the cavity only when dentin chips hinder the visibility of relevant anatomical structures.[29]

The access cavity should be adequately prepared in accordance with the laws of Krasner and Rankow.[14] The Law of Concentricity is illustrated in Figure 10. Proper access cavity preparation enhances visualization of the pulpal floor, facilitates diagnosis, and ensure straight-line access to the canal orifices. Common errors during the standard errors access cavity preparation, such as incomplete removal of caries, inadequate deroofing of the pulp chamber, over preparation, or perforations, can significantly compromise the ability to locate both main and accessory canals.[14,30] In cases where the pulp is vital, bleeding points on the pulpal floor often indicate the presence of canal orifices. In a few cases, blood may track into isthmus areas and fins. These anatomical landmarks serve as roadmap for identifying canal morphology and are clinically referred to as the “Red Line Test”.[10]

Removal of pulp tissue should begin with a thorough assessment of the tooth anatomy as well as surrounding structures. Prior to initiating the mechanical phase of access preparation, all defective restorations and caries lesions must be eliminated, as the presence of marginal leakage or residual caries may allow bacterial contamination during or after treatment.[14] To effectively debride the root canal system, both the coronal portion of the system, including the pulp chamber and the radicular pulp must be clearly identified. The clinician must be determining the exact number of orifices in each tooth without causing iatrogenic damage. The most reliable and safe approach is to visualize the entire pulpal floor and employ various anatomic landmarks.[30,31] it has been demonstrated that the set of principles proposed by Krasner and Rankow Law can be applied to accurately locate canal orifices on the pulp chamber floor. These laws are summarized in Table I.[32]

Table 1. Laws proposed by Krasner and Rankow for pulp chamber anatomy[32]

Law	**Definition**
Law of centrality	The floor of the pulp chamber is always located in the centre of the tooth at the level of the CEJ.
Law of concentricity	The walls of the pulp chamber are always concentric to the external surface of the tooth at the level of the CEJ.
Law of the CEJ	The CEJ is the most consistent, repeatable landmark for locating the position of the pulp chamber
Law of symmetry 1	Except for maxillary molars, the orifices of the canals are equidistant from a line drawn in a mesial-distal direction, through the pulp chamber floor.
Law of symmetry 2	Except for the maxillary molars, the orifices of the canals lie on a line perpendicular to a line drawn in a mesial-distal direction across the centre of the floor of the pulp chamber.
Law of colour change	The colour of the pulp-chamber floor is always darker than the walls.
Law of orifice location 1	The orifices of the root canals are always located at the junction of the walls and the floor.
Law of orifice location 2	The orifices of the root canals are located at the angles in the floor-wall junction.
Law of orifice location 3	The orifices of the root canals are located at the terminus of the root developmental fusion lines.

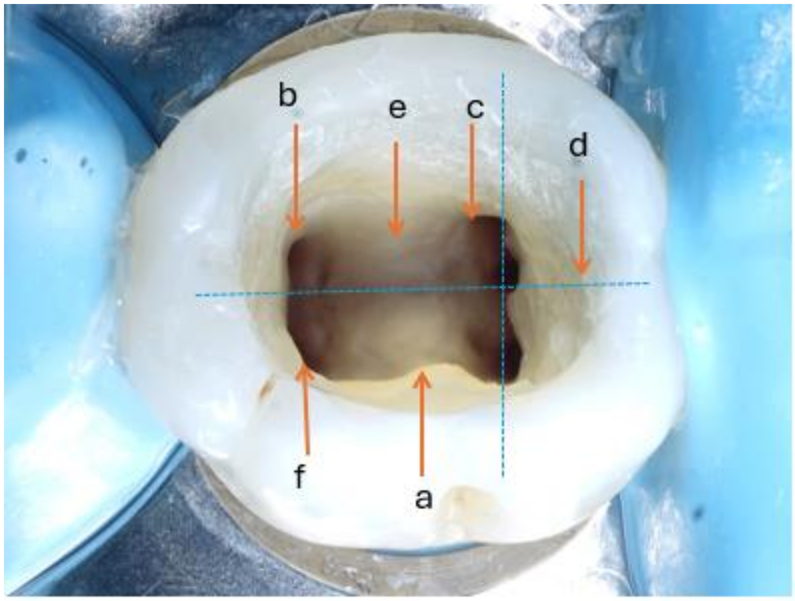

Figure 10. laws of Krasner and Rankow. (a) Law of centrality, (b) Law of concentricity, (c) Law of the CEJ, (d) Law of symmetry, (e) Law of colour change, (f) Law of orifice location

According to Krasner and Rankow, the pulp chamber of every tooth is located at the centre of the tooth at the level of the cementoenamel junction (CEJ), a principle referred to as the *Law of Centrality*. This law serves as a fundamental guide during the initiation of access preparation. However, it is essential for the operator to recognize that the law holds true only at the CEJ level and is independent of the occlusal anatomy. Since the pulp chamber is consistently cantered at the CEJ, the initial penetration with the bur should be directed towards the centre of the CEJ. [31,32]

Visualization of the final outline of the pulp chamber can be further aided by another anatomical principle, the *Law of Concentricity*. This law states that the walls of the pulp chamber are concentric with the to external surface of the tooth at the CEJ level. Understanding this principle helps the clinician to extend the access cavity appropriately. Any bulge of the CEJ in each direction indicates a corresponding extension of the pulp chamber in that direction. For example, if the tooth is narrow mesiodistally, the clinician can anticipate that the pulp chamber will also be narrow in the mesiodistal dimension.[31–33]

One of the most challenging steps in endodontic access preparation is determining when the access is complete. To make this determination, clinicians rely on the *Law of Colour Change.* This principle states that the floor of the pulp chamber is consistently darker than the surrounding walls. The Law of Colour Change thus serves as a critical guide for recognizing when the access has been adequately prepared. Since the chamber walls are lighter, d distinct junction forms where there the lighter walls meet the darker chamber floor.[31–33] This junction, referred to as the floor-wall junction (Figure 10e), extends circumferentially across the entire pulp chamber floor. Access is considered complete once the operator can clearly visualize the floor-wall junction encircling the chamber floor 360 degrees. The precise identification of this junction is regarded as the single most important step in the access phase of endodontic treatment.[33]

Figure.10 illustrates a completed access, where the chamber walls converge with the floor along the entire perimeter. In addition, according to Krasner and Rankow's *Laws of Symmetry*, the spatial distribution of canal orifices, particularly in mandibular teeth, can be anticipated with relative predictability. *Law of Symmetry 1* states that, except for maxillary molars, canal orifices are equidistant from a line drawn mesiodistally through the center of the pulp chamber floor. *Law of Symmetry 2* further specifies that, except in maxillary molars, canal orifices tend to align along a line perpendicular to this mesiodistal reference line. These anatomical principles are clinically significant, as they enhance the detection of additional canals, such as middle mesial canals in mandibular molars, and improve the accuracy and efficiency of endodontic access cavity preparation.[31–33]

The application of Krasner and Rankow's *Laws of Symmetry* proved particularly relevant in this case. During access cavity preparation, these principles provided a valuable guide for predicting the expected positions of the main canal orifices and assessing the likelihood of the additional canal anatomy. In mandibular molars, identifying the middle mesial canal (MMC) is often challenging due to its variable prevalence and frequently indistinct orifice, which may be situated between the mesiobuccal and mesiolingual canals.[10] By applying the *Law of Symmetry*, the clinician was able to systematically explore the developmental groove region, which ultimately facilitated the detection of the MMC. This highlights the importance of incorporating anatomical principles into clinical practice to minimize the risk of missed canals and thereby enhance the overall prognosis of root canal treatment.

The orifices of the middle mesial canal (MMC) can be identified by carefully examining the pulp chamber floor with a sharp endodontic explorer (DG16), a small stiff stainless-steel K-file, or micro-openers.[10] Following proper access cavity preparation, a sharp endodontic explorer should be passed along the developmental groove between the mesiobuccal (MB) and mesiolingual (ML) canals. Careful probing of this area may reveal a tactile ''catch" or ''stick" sensation, which indicates the presence of an accessory canal. Once identified, the canal can be negotiated using a gentle watch-winding motion until reaching the working length, with an adequate volume of sodium hypochlorite placed in the pulp chamber to aid disinfection.[10,34] Micro-openers are flexible ISO-sized hand instruments with 7 mm K-type flutes mounted on a handle. Their exaggerated taper enhances tensile strength, and they are specially designed for use under magnification.[10]

The guided troughing technique can enhance the likelihood of locating the middle mesial canal (MMC). Ultrasonic tips are most used for this purpose. Since most MMC orifices are situated close to the mesiolingual (ML) canal, the clinician should begin troughing from from the ML canal and gradually progress along the developmental groove toward the MB canal. The troughing should be directed apically at the expense of the mesial–axial wall and away from the furcation area (danger zone), as the dentin thickness in this region is often less than 1 mm, thereby increasing the risk of strip perforation. During ultrasonic troughing, the the pulp chamber floor should be frequently examined for grooves packed with dentin chips as their removal may reveal hidden orifices (the "White Line Test"). Troughing should always be performed under magnification to minimize unnecessary tooth structure removal and to facilitate the identification of root canal orifices.[10,35]

The ultimate objective of root canal preparation is to shape, clean, disinfect and obturate the canal system. This is achieved through the synergistic combination of the mechanical action of endodontic files and the chemical properties of irrigants, while preserving the original anatomy of the root canal.[36] Cleaning and shaping of middle mesial canal (MMC) are particularly challenging, as these canals are often narrow, tortuous, curved, or confluent with one of the primary root canals. Therefore, meticulous instrumentation and irrigation protocols are essential to achieve effective debridement while minimizing procedural errors such as ledge formation, transportation, or perforation.[10,37] Establishing a proper glide path, selecting appropriate rotary files, and applying correct techniques are critical to ensuring efficient cleaning and shaping without complications.[10,38] K-files with a high buckling resistance or C Pilot files can efficiently negotiate narrow and tortuous canals without excessive bending, enabling safe progressing through complex anatomies.[39] These files should always be used in the presence of sodium hypochlorite, with a watch-winding motion to facilitate the smooth advancement within the root canal system.[10] The canals should be adequately enlarged adequately to at least a #10 K-file size before initiating a rotary file for the glide path. The introduction of nickel-titanium (NiTi) instruments has significantly improved the quality of root canal shaping due to the alloy's elasticity and flexibility. Compared to stainless-steel files, NiTi rotary system substantially reduce canal transportation and enhance overall shaping outcomes.[10,40]

Over the past decade, single-file systems utilizing reciprocating motion have gained considerable popularity. These systems are theoretically designed to shape the root canal with a single instrument, thereby making the procedure faster, although less gradual, compared to multi-file rotary system.[41] The Reciproc system (VDW, Munich, Germany) is manufactured from a nickel-titanium NiTi alloy known as M-wire, which is produced through an innovative thermal treatment process.[42] Compared with multi-file rotary system, reciprocating single-file system offer several advantages, including reduced treatment time, enhance safety, and greater file longevity.[41,43]

In reciprocating motion, the instrument rotates in one direction before reversing its path, without completing a full rotation. During the counterclockwise movement, the file engages and cuts dentin, while the clockwise movement disengages the instrument, thereby preventing taper lock and reducing stress on the file.[41] This alternating motion significantly increase the instrument's resistance to both cyclic and torsional fatigue.[43]

More recently, Reciproc Blue (VDW GmbH, Munich, Germany) was introduced as an advancement of the original Reciproc system. Although both instrument share the same geometric design, Reciproc blue undergoes a modified thermal treatment that alters its molecular structure, resulting in superior flexibility and greater resistance to cyclic fatigue-related fractures.[44] An additional improvement of Reciproc Blue is the ability to pre-bend the instrument. The manufacturer claims that the new technology and design improve the flexibility of the file.[44–46]

Following biomechanical preparation, the subsequent critical step is obturation. The primary objective of root canal therapy is to achieve a hermetic seal of root canal system and prevent reinfection.[47] Various obturation techniques may be employed for middle mesial canal (MMC), with the choice depending on operator expertise, canal morphology, and the availability of appropriate materials and equipment.[10,47] In this case, the MMC were separated from the main mesial canals and were obturated using single-cone technique in combination with a bioceramic sealer, followed by vertical compaction with heated endo plugger.[10] The single-cone technique with bioceramic sealer has demonstrated better results compared to the lateral condensation technique and may serve as a reliable alternative for obturating the MMC.[10]

Furthermore, the anatomical complexity of MMCs frequently harbors microbial biofilms that are challenging to eliminate, thereby necessitating the combined use of mechanical instrumentation and advanced irrigation protocols, such as passive ultrasonic irrigation or sonic activation, to achieve optimal disinfection.[10,48] Effective disinfection, coupled with three-dimensional obturation of these canals, has been strongly associated with higher treatment success rates and la reduced incidence of post-treatment disease.[48,49] Consequently, the integration of conservative canal shaping, efficient irrigation strategies, and appropriate obturation techniques is essential for achieving favorable outcomes in cases involving anatomical variations such as MMC.

Once endodontic therapy is completed, attention must shift to the restorative phase. Endodontically treated teeth are structurally weaker than vital teeth due to the loss of structural integrity resulting from extensive caries, trauma, aggressive canal flaring during endodontic procedure, and other treatment-related interventions.[50] This structural compromise adversely affect their long-term survival and longevity, as such teeth are more prone to fracture and therefore require optimal restorative management.[50,51] To overcome this challenge, restorative materials with dentin-like mechanical behavior have been developed. One such innovation is *Ever-X Posterior* (GC, Tokyo, Japan), introduced in 2013, which was specifically designed to mimic the stress-absorbing properties of sound dentin and thereby enhance the fracture resistance of restored teeth. This material consists of a resin matrix reinforced with randomly orientated E-glass fibres and inorganic particulate fillers, collectively referred to as short fibre-reinforced composite (SFRC). The fibres act as stress relievers, reinforcing the tooth structure internally while preventing crack propagation. According to the manufacturers, Ever-X Posterior has primarily been as a bulk core build-up material in bulk for the restoration of both vital and nonvital teeth.[20,21]

Following establishment of core build-up, the restorative phase should progress to the placement of adhesive restorations. These restorations not only fulfil esthetic requirements but also adhere to bioeconomic principles while providing delivering biomechanical reinforcement to the remaining tooth structure. In cases of large cavities requiring cusp coverage, adhesively cemented restorations are regarded as the most favorable clinical option, as they promote superior stress distribution, reduces the risk of catastrophic failure, and enhance the longevity of endodontically treated teeth. An *adhesive indirect restoration* is defined as a partial crown restoration fabricated made in composite or full ceramic, which must passively seat and adhesively cemented in a cavity with specific characteristics. Indications for such restorations are reinforced by additional factors, including the presence of minimal cervical enamel (< 1 mm height and 0.5 mm in width), or its complete absence, as well as cervical concavities.[52,53]

In the present case, the thickness of the remaining walls of tooth #46 was precisely measured using a dental calliper, revealing a buccal wall thickness of approximately 2 mm, mesial and distal walls of less than 2 mm, and the complete absence of the lingual wall (Figure 3A). These conditions further supported the indication for adhesively cemented indirect restoration, with the aim of optimizing biomechanical reinforcement and ensuring long-term survival of the tooth. Since indirect restorations are particularly indicated in wide cavities associated with substantial hard tissue loss, the critical thickness of the remaining walls becomes a decisive factor in determining whether a wall should be preserved or replaced, especially when the walls undercut and require appropriate build-up or block-out prior to final restoration. [52–54]

The principles of the Morphology-Driven Preparation Technique (MDPT), as emphasized by Veneziani, aim to minimize unnecessary removal of sound tooth structure by strictly respecting the tooth's natural morphology. This technique advocates for a minimally invasive approach that preserves pericervical dentin, reduces dentin exposure, and maximizes enamel preservation, particularly in areas essential for adhesive. Consequently, the preparation design is guided by the residual morphology and the thickness of the remaining walls, rather than relying conventional geometric guidelines. Based on these principles, an adhesively cemented lithium disilicate overlay was selected as the definitive restoration. [23,52]

Overlays are full cusp-coverage restorations indicated for large class II cavities with unsupported axial walls and the absence of both marginal ridges. In vital teeth, the presence of cracks in enamel and dentin, and in endodontically treated teeth the absence of a marginal ridge, necessitate total cusp coverage even when residual walls of adequate thickness remain. Lithium disilicate overlays not only offer excellent aesthetics and durability but also mimic the biomechanical behaviour of natural tooth structure, thereby ensuring favourable stress distribution and reducing the risk of catastrophic fractures in structurally compromised teeth. The clinical performance of lithium disilicate (LDS) CAD/CAM overlay and crown is well-documented, with reported survival rates of 93% after 6 years and 80.1% after 15 years.[23,24,54] The definitive indirect overlay using lithium disilicate in combination with adhesive cementation provided a durable and aesthetic restorative outcome.

CONCLUSION

The detection and management of middle mesial canals are criticala for chieving successful endodontic outcomes in mandibular first molars. In this case, precise identification of the middle mesial canal (MMC) was facilitated through meticulous exploration and magnification, highlighting the clinical importance of recognizing anatomical variations in mandibular molars.

Thorough cleaning and shaping, combined with irrigation and three-dimensional obturation protocol, ensures effective disinfection and achieves a hermetic seal, preventing bacterial ingress and supporting long-term periapical healing. For definitive restoration, an adhesively cemented lithium disilicate overlay was selected, offering superior aesthetics, optimal biomechanical reinforcement, cusp stabilization, and enhanced longevity of the tooth.

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