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CASE REPORT

CBCT-guided nonsurgical endodontic treatment of molar-incisor malformation: a 4- to 6-year follow-up case series in pediatric patients

Hyo-Jin Jo[1], Jung-Hong Ha[2,]*

[1]Department of Conservative Dentistry, School of Dentistry, Kyungpook National University, 41940 Daegu, Republic of Korea
[2]Department of Conservative Dentistry, School of Dentistry, IHBR, Kyungpook National University, 41940 Daegu, Republic of Korea

***Correspondence**
endoking@knu.ac.kr
(Jung-Hong Ha)

Abstract

Background: Molar-Incisor Malformation (MIM) is a recently identified developmental dental anomaly. It is characterized by normal crown morphology, but exhibits short, morphologically altered roots, predominantly affecting the permanent first molars and occasionally the incisors. Because MIM results in a complex internal anatomy and calcified canal structures, standardized treatment protocols have not yet been established, and extraction is often recommended. This case series reports successful nonsurgical endodontic management of MIM-affected molars with long-term follow-up aided by cone-beam computed tomography (CBCT). **Cases**: Three pediatric patients diagnosed with MIM in their first permanent molars underwent cone-beam computed tomography-guided nonsurgical endodontic treatment. Case 1 presented with a fused root and an immature palatal apex. This case required revascularization of the palatal root, whereas the remaining canals were treated nonsurgically. Case 2 had six distinct canals in the maxillary first molar. All the canals identified using CBCT were successfully treated. Case 3 involved a left mandibular first molar with five canals, including a mid-mesial canal. This case was managed with nonsurgical root canal treatment despite the patient's limited cooperation. Across all cases, CBCT enabled accurate identification of canal morphology, detection of additional and calcified canals, and formulation of appropriate treatment strategies based on anatomical characteristics. **Conclusion**: Despite the severely compromised root anatomy, CBCT-supported nonsurgical endodontic treatment enabled successful long-term preservation of MIM-affected molars. All cases maintained stable clinical and radiographic status throughout the extended follow-up period. CBCT serves as a critical diagnostic adjunct, providing a precise three-dimensional assessment of complex canal configurations to guide treatment decisions. With careful case selection, nonsurgical endodontic management is a conservative and viable alternative to extraction. This approach is particularly valuable for pediatric patients in whom dental preservation is required until craniofacial growth is completed.

Keywords

Molar-incisor malformation; Cone-beam computed tomography; Endodontic treatment; Root malformation; Pediatric dentistry

1. Introduction

Most pediatric patients require endodontic treatment during their first visit to the pediatric dental clinic for a permanent molar. However, challenging cases with complex internal root canal morphologies are often referred to endodontic or conservative dentistry specialists. Severe morphological abnormalities extending from the crown to the root are classified as molar-incisor malformations (MIM).

MIM was first described in 2014 and was initially considered a variant of Dentin Dysplasia type I (DD type I) rather than a novel entity, owing to the lack of documented cases. Although MIM shares certain clinical features with DD type I, a significant distinction is that DD type I has a hereditary basis [1]. MIM primarily affects the primary second molars, permanent central incisors, and first molars, and its occurrence may or may not be associated with systemic conditions [2].

Standardized treatment strategies for MIM have not yet been established. Most recommendations advocate a conservative symptom-driven approach, with treatment deferred until clinical symptoms appear. Once symptomatic, extraction is usually suggested instead of conventional root canal treatment [3]. According to a systematic review by Jensen *et al.* [4], out of 130 MIM cases across 23 studies, root canal treatment was performed in only two cases, whereas the vast majority resulted in extraction or active surveillance. This decision typically arises from the teeth's irregular morphology and the resulting procedural complexity. Moreover, symptom recurrence may result from missed canals, instrument separation, or inadequate access owing to severe curvature. The high risk of symptom recurrence remains a major challenge in the management of MIM-affected teeth.

Cone-beam computed tomography (CBCT) provides three-dimensional cross-sectional images, enabling detailed evaluation of tooth anatomy from multiple angles. This modality is particularly valuable in MIM cases with complex root morphology, as it enables accurate identification and management of atypical canal configurations. Furthermore, CBCT assessments can guide clinicians in selecting the most appropriate treatment approach. Variations in the coronal third are frequently manageable with non-surgical root canal treatment, whereas apical complexities may require surgical intervention or extraction. Such considerations are particularly critical in pediatric patients, for whom both anatomical complexity and limited cooperation must be considered. This case series describes successful nonsurgical root canal management of first molar with multiple anatomical variations facilitated by CBCT imaging.

2. Case presentation

2.1 Case 1

A 13-year-old boy was referred from the Department of Pediatric Dentistry to the Department of Conservative Dentistry for specialized endodontic management of the left maxillary first molar, which was painful on percussion. Endodontic treatment was initiated, and periapical and panoramic radiographs revealed chronic apical periodontitis with incomplete root formation, with a preoperative periapical index (PAI) score of 5 (Fig. 1A–C) [5]. Because two-dimensional imaging did not consistently reveal the actual number of roots and canals, CBCT with a medium field of view (FOV) was performed using the following parameters: tube voltage, 85 kVp, and 10 mA. The imaging area was an 80 mm × 80 mm × 50 mm diameter cylinder, with a voxel size of 0.12 mm [6]. CBCT revealed an anomalous root fusion involving the mesiobuccal (MB), distobuccal (DB), and palatal (P) roots (Fig. 1D,E). Despite the severe anatomical complexity revealed by imaging, endodontic intervention was planned because the patient exhibited a high level of cooperation, which allowed for a clinical environment comparable to that of an adult. The patient's and legal guardian's readiness to receive endodontic treatment impacted the delicate procedures that might otherwise be unfeasible in a pediatric patient. Vascularization was performed to preserve the tooth and facilitate further development and elongation of the palatal root, which served as the primary source of periodontal support. Concurrently, nonsurgical root canal treatment was planned for the MB and DB root canals, while managing the structural irregularities of the MIM-affected molars.

Minimal instrumentation was performed using a #15 K-file (M access; Dentsply Sirona, Ballaigues, VD, Switzerland) to scout and determine the working length of the palatal canal before revascularization. The canal was irrigated with 2.5% sodium hypochlorite (NaOCl) using a 30-gauge, side-vented needle (TruNatomy Irrigation Needle; Dentsply Sirona, Ballaigues, VD, Switzerland) and medicated with calcium hydroxide paste (Calcipex II; LOT Q8X, Nippon Shika Yakuhin, Shimonoseki, Japan) between appointments [7]. After three irrigation sessions, the clinical symptoms and purulent discharge resolved, enabling complete disinfection. To release growth factors from the dentin, a final 20 mL flush of 17% Ethylenediaminetetraacetic acid (EDTA, Smart-prep; Il-Chung dental Co, SPS2207001, Cheongju, Republic of Korea) was performed [8]. Subsequently, bleeding was induced by gentle over-instrumentation of the apical region, and a collagen matrix was placed over the resulting blood clot. Mineral trioxide aggregate (MTA, ProRoot MTA; Dentsply Sirona, USA) was then placed over the collagen plug, and a distilled water-moistened cotton pellet was applied to provide moisture and allow the MTA to set. Notably, all clinical procedures, including the delicate revascularization steps and the challenging exploration of calcified orifices, were performed under a dental microscope (OPMI pico; Carl Zeiss, Oberkochen, BW, Germany) to ensure maximum precision and minimize iatrogenic risk [6]. Because multiple attempts to negotiate the mesiobuccal (MB) and distobuccal (DB) canal orifices were unsuccessful due to severe calcification, the pulp chamber was debrided with ultrasonics and sealed with a composite resin (Gradia Posterior A2; GC Corp., Tokyo, Japan). Despite the inability to locate these specific canals, the tooth remained asymptomatic. Follow-up examinations at 1, 3, 6, and 12 months revealed no radiographic abnormalities (Fig. 2A,B). The initial percussion tenderness had completely resolved, with normal mobility and no pain on palpation. Although no increase in root length was observed following revascularization, the 1-year periapical radiograph demonstrated a distinct calcific barrier beneath the MTA (Fig. 2C). Throughout the 5-year and 6-month follow-up period, the tooth maintained functional stability, with the absence of pain, swelling, or sinus tracts, and the PAI score had decreased from 5 to 3 (Fig. 2D).

2.2 Case 2

A 10-year-old patient presenting with buccal space swelling associated with the right maxillary first molar was referred to the Department of Pediatric Dentistry at a local dental clinic. Emergency incision and drainage were performed, and the patient was subsequently referred to the Department of Conservative Dentistry for further endodontic evaluation (Fig. 3A,B). Following the procedure, the pain was alleviated; however, a sinus tract persisted on the attached buccal gingiva. Panoramic and periapical radiographs revealed multiple MIM affecting all the first molars in both arches, with apical periodontitis corresponding to a PAI score of 5 at the right maxillary first molar.

Given the patient's young age and the potential complications associated with extraction of the maxillary right first molar, nonsurgical root canal treatment was selected as the primary treatment option. Although extraction was a possible alternative, the patient demonstrated excellent cooperation

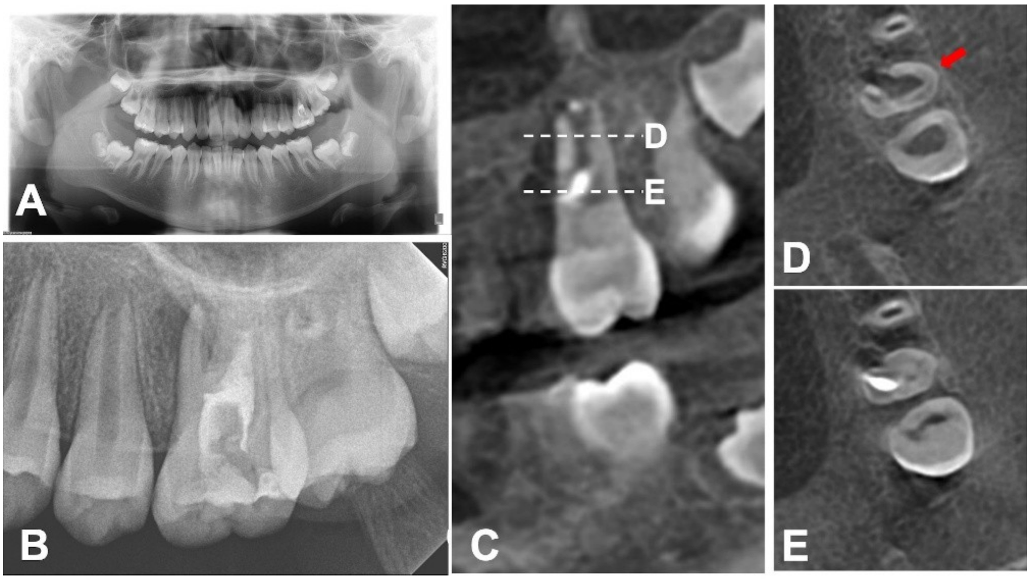

FIGURE 1. Preoperative Radiographs. (A) Panoramic radiograph and periapical radiograph showing the previously initiated endodontic treatment on tooth #26. (B) The palatal root has an immature, open apex. (C) Sagittal CBCT view of the maxillary molar. Dashed lines D and E indicate the respective levels of the apical and coronal axial image. (D) Axial CBCT image (apical area). The red arrow points to the fused morphology of the mesiobuccal (MB), distobuccal (DB), and palatal (P) root. (E) Axial CBCT image (coronal area).

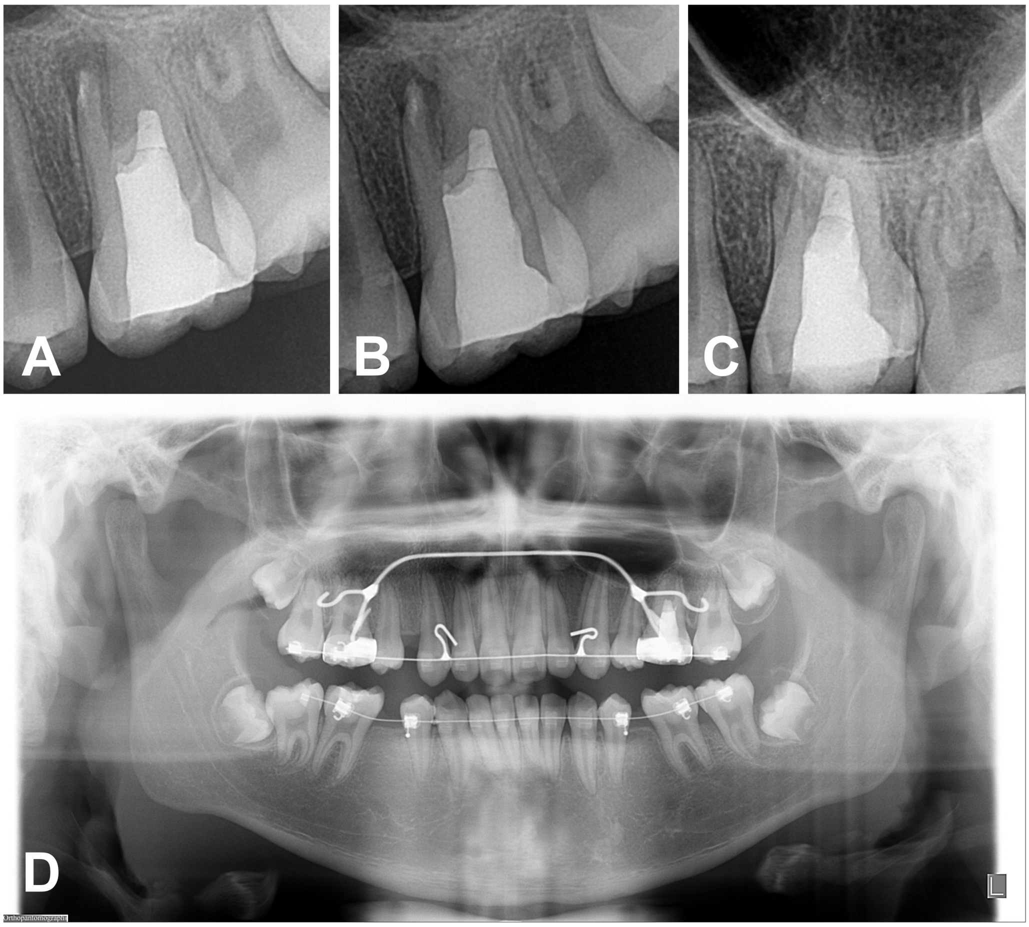

FIGURE 2. Serial postoperative radiographs. (A) Periapical radiograph following root canal treatment. (B) Periapical radiograph at the 3-month recall. (C) Periapical radiograph at the 1-year recall, showing a calcific barrier directly beneath the mineral trioxide aggregate (MTA). (D) Panoramic radiograph at 5-year and 6-month recall. The radiographs revealed no remarkable findings, and the patient remained asymptomatic.

and adequate mouth opening, allowing a complex endodontic treatment to be performed safely. Furthermore, the patient's legal guardians strongly preferred tooth preservation over immediate extraction, and root canal treatment was therefore performed. To evaluate the complex root canal anatomy, including the actual number of roots and canals, a medium FOV CBCT scan was acquired using the following parameters: 85 kVp and 10 mA. The imaging volume was a cylindrical field measuring 80 mm × 80 mm × 50 mm, reconstructed with a voxel size of 0.12 mm. The CBCT images revealed six distinct canals: three in the mesiobuccal root, one in the distobuccal root, and two in the palatal root (Fig. 3C–F).

Nonsurgical root canal treatment was performed as follows. An access cavity was created after the rubber dam was isolated. CBCT images were used to identify the precise location of each canal orifice before canal negotiation, and these preoperative findings served as a navigational guide during treatment, facilitating successful canal localization despite the structural distortions associated with MIM. All procedures from orifice identification to canal negotiation were performed under a dental operating microscope (OPMI Pico) to maximize visual clarity and precision. Working lengths were determined using a #15 K-file and an electronic apex locator (iRoot; Meta Biomed, Cheongju, Korea). The canals were subsequently enlarged to X1 (size 17/.04) and X2 (size 25/.06), using the ProTaper Next system (Dentsply Sirona). During each visit, canal irrigation was performed using 2.5% NaOCl delivered through a 30-gauge needle (TruNatomy Irrigation Needle) positioned 3 mm short of its working length. The irrigant was agitated for 1 min using an EndoActivator (sonic irrigation activation device, Dentsply Sirona) (Fig. 4). Calcium hydroxide (Calcipex II) was placed as an intracanal medicament at each visit, and appointments were scheduled at 1-week intervals to ensure thorough disinfection.

After four treatment visits, the buccal sinus tract resolved and symptoms subsided. The root canals were obturated with gutta-percha points and an epoxy resin-based sealer (AH Plus zet; LOT 2505000785, Dentsply Sirona) using the continuous wave condensation technique. Subsequently, a coronal restoration was performed using a composite resin (Gradia Posterior A2; GC, Tokyo, Japan). Periodic follow-up examinations at 1 month, 6 months, 1 year, and 6 years revealed normal periapical healing with no pain, swelling, sinus tract, percussion sensitivity, or abnormal mobility, and the PAI score decreased from 5 to 2 (Fig. 5).

2.3 Case 3

A 10-year-old boy was referred by a local dental clinic to the Department of Pediatric Dentistry for endodontic evaluation. The patient reported pain on percussion of the left mandibular first molar. Clinical and radiographic examinations indicated chronic apical periodontitis associated with pulpal necrosis, corresponding to a PAI score of 5 (Fig. 6A,B). The panoramic

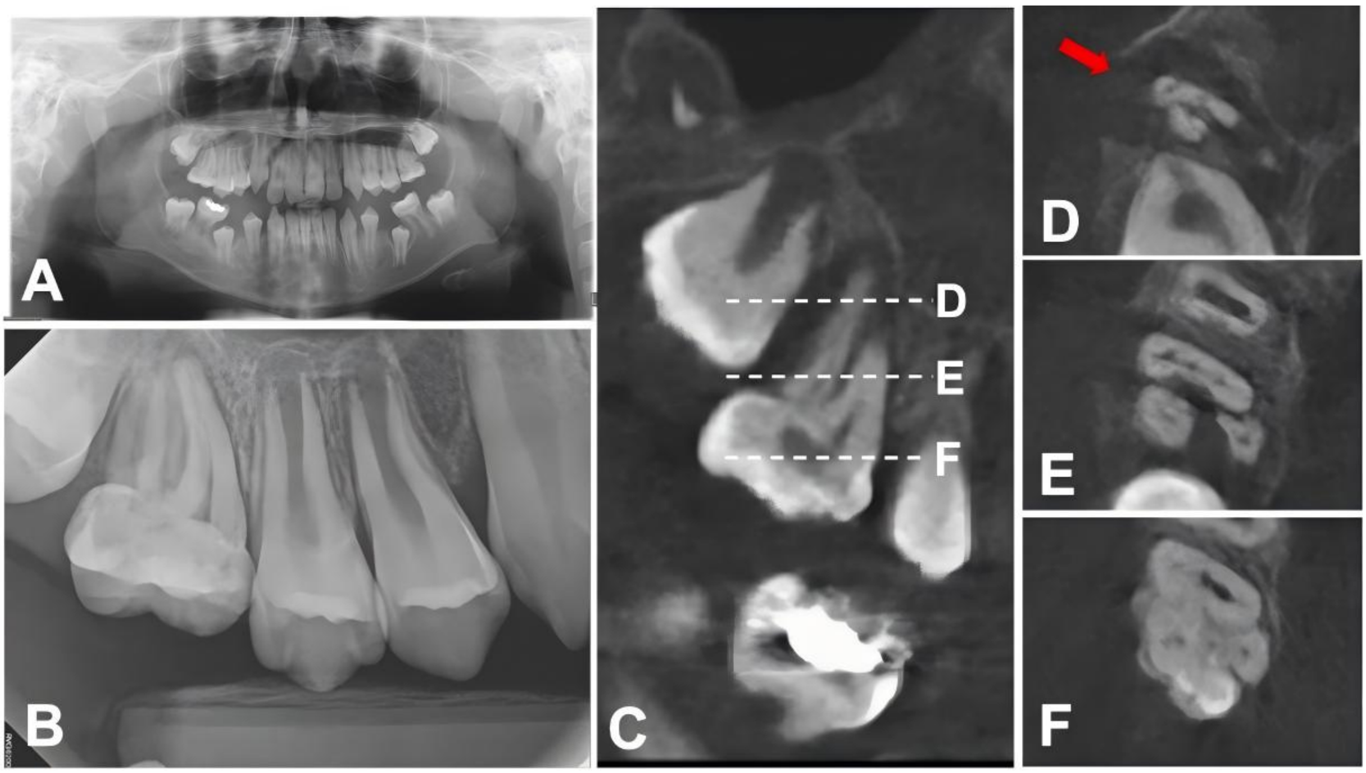

FIGURE 3. Preoperative Radiographs. (A) Initial panoramic radiograph. Molar-incisor malformation is evident in all maxillary and mandibular first molars. (B) Periapical radiograph showing apical periodontitis at the right maxillary first molar. (C) Sagittal CBCT view of the maxillary molar. Dashed lines D, E, and F indicate the respective levels of the apical, middle, and coronal axial image. (D) Axial CBCT image (apical area). The red arrow points to a large periapical lesion. (E) Axial CBCT image (middle area). The CBCT image reveals six canals: three mesiobuccal, two palatal, and one distobuccal. (F) Axial CBCT image (coronal area), showing complex internal anatomy.

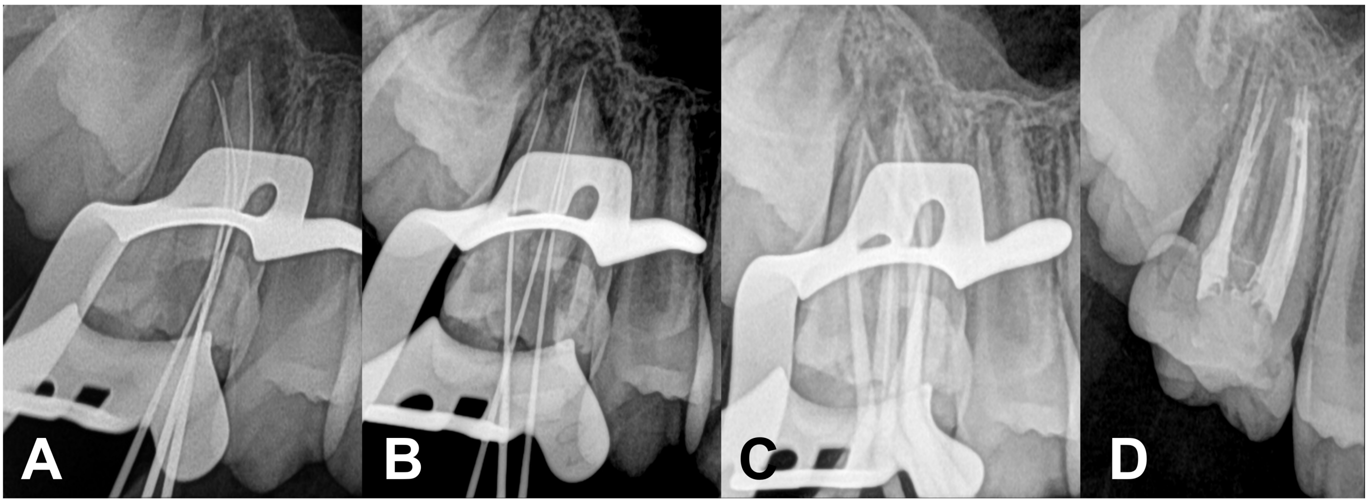

FIGURE 4. Serial periapical radiographs taken during root canal treatment. (A) Working length determination radiograph using a #15 K-file. (B) Working length determination radiograph using a #15 K-file. (C) Master cone filling radiograph. (D) Post-obturation (canal filling and core restoration).

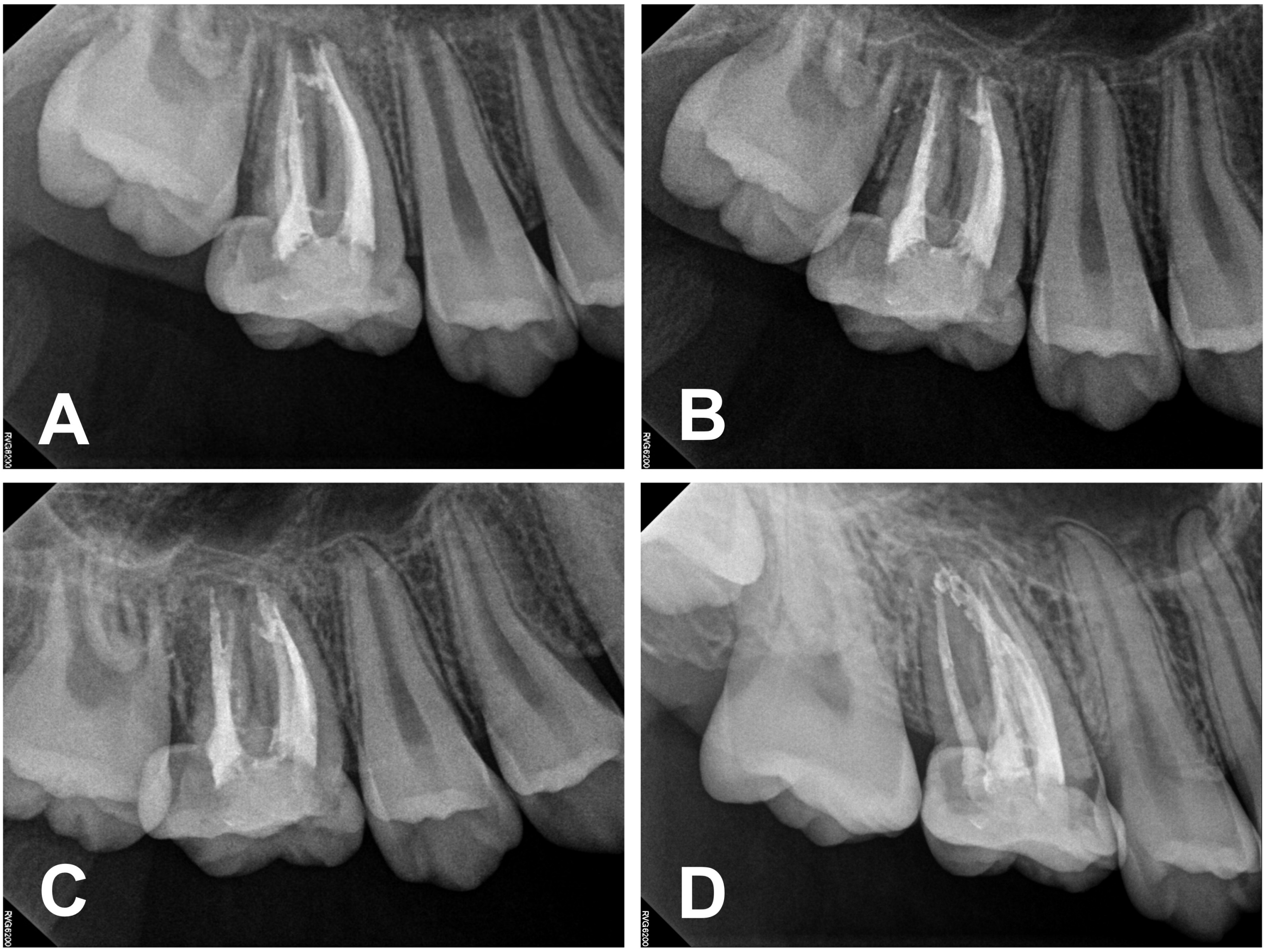

FIGURE 5. Periapical radiographs at follow-up recalls: (A) 1 month, (B) 6 months, (C) 1 year, and (D) 6 years. All radiographs demonstrate normal, healed periapical tissue.

image did not reveal a tooth germ for the third molar, making alternative treatment options, such as extraction followed by mesial traction of the posterior teeth, unfeasible. Therefore, nonsurgical root canal treatment was planned to preserve the tooth for as long as possible. To evaluate the root canal configuration, a medium FOV CBCT scan was acquired using the following parameters: 80 kVP and 8 mA. The imaging area was a 100 mm × 100 mm × 80 mm diameter cylinder, with voxel reconstruction of 0.2 mm. CBCT imaging revealed a complex canal system comprising three mesial canals and two distal canals: mesiobuccal (MB), mesiolingual (ML), mid-mesial (MM), distobuccal (DB), and distolingual (DL) (Fig. 6C–F). The precise location of each canal orifice was pre-identified through a detailed analysis of CBCT data, supporting the clinical judgment that nonsurgical root canal treatment is feasible despite the high anatomical complexity. Accordingly, nonsurgical root canal treatment was performed.

Nonsurgical root canal treatment was performed as follows. Following rubber dam isolation and access cavity preparation, the working length was determined using a #15 K-file and an electronic apex locator (iRoot; MetaBiomed). Owing to the patient's young age, restricted mouth opening, and poor cooperation, initial canal shaping was performed 1 mm short of the tentative working length. The length was verified by inserting a gutta-percha cone and obtaining a radiograph (Fig. 7A). The distolingual canal could not be negotiated because of severe calcification but was found to be fused with the distobuccal canal approaching the root apex. The final instrumentation was completed up to a size of 40/.04 using a HyFlex EDM finisher (endodontic motor-driven NiTi system, Coltene, Altstätten, SG, Switzerland). During the procedure, irrigation with 2.5% NaOCl was performed using a 30-gauge needle (TruNatomy Irrigation Needle) inserted 3 mm short of the working length. Each irrigation session was followed by 1 min of agitation using an EndoActivator (Dentsply Sirona) to ensure adequate disinfection of the complex canal system. Calcium hydroxide (Calcipex II) was placed as an intracanal medicament at each visit, and appointments were scheduled at 1-week intervals to ensure thorough disinfection.

After seven visits, all symptoms were resolved. The root canals, except the DL canal, were obturated with gutta-percha points and an epoxy resin sealer (AH Plus; Dentsply Sirona), using the continuous wave condensation technique. The core was then filled with a composite resin (Gradia Posterior A2; GC) (Fig. 7B). Follow-up examinations at 4 months and at 1, 2, and 4 years revealed normal periapical healing with no pain, swelling, sinus tract formation, or abnormal mobility, and the PAI score had decreased from 5 to 1 (Fig. 8).

3. Discussion

Reports have demonstrated the feasibility of nonsurgical endodontic treatment of MIM-affected teeth. Successful treatment requires adequate cleaning and disinfection of the root canal system, followed by three-dimensional obturation. In this case series, outcomes were assessed using combined clinical and radiographic criteria based on established endodontic outcome measures. According to Ng *et al.* [9], strict success

FIGURE 6. Preoperative Radiographs. (A) Initial panoramic radiograph. (B) Periapical radiograph showing molar-incisor malformation in the left mandibular first molar. (C) Sagittal CBCT view of the maxillary molar. Dashed lines D, E, and F indicate the respective levels of the apical, middle, and coronal axial image. (D) Axial CBCT image (coronal area), showing complex internal anatomy. (E) Axial CBCT image (middle area), revealing five canals in the left mandibular first molar: three mesiobuccal, two distal. (F) Axial CBCT image (apical area). Widening of the periodontal ligament (PDL) space is observed at the distal root apex.

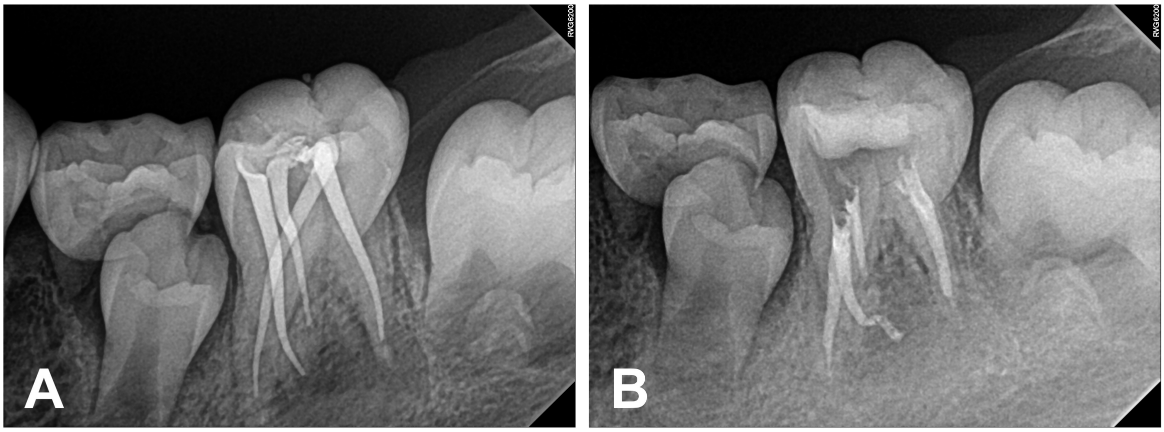

FIGURE 7. Serial periapical radiographs taken during root canal treatment. (A) Working length determination radiograph using a gutta-percha cone. (B) Post-obturation radiograph showing canal filling.

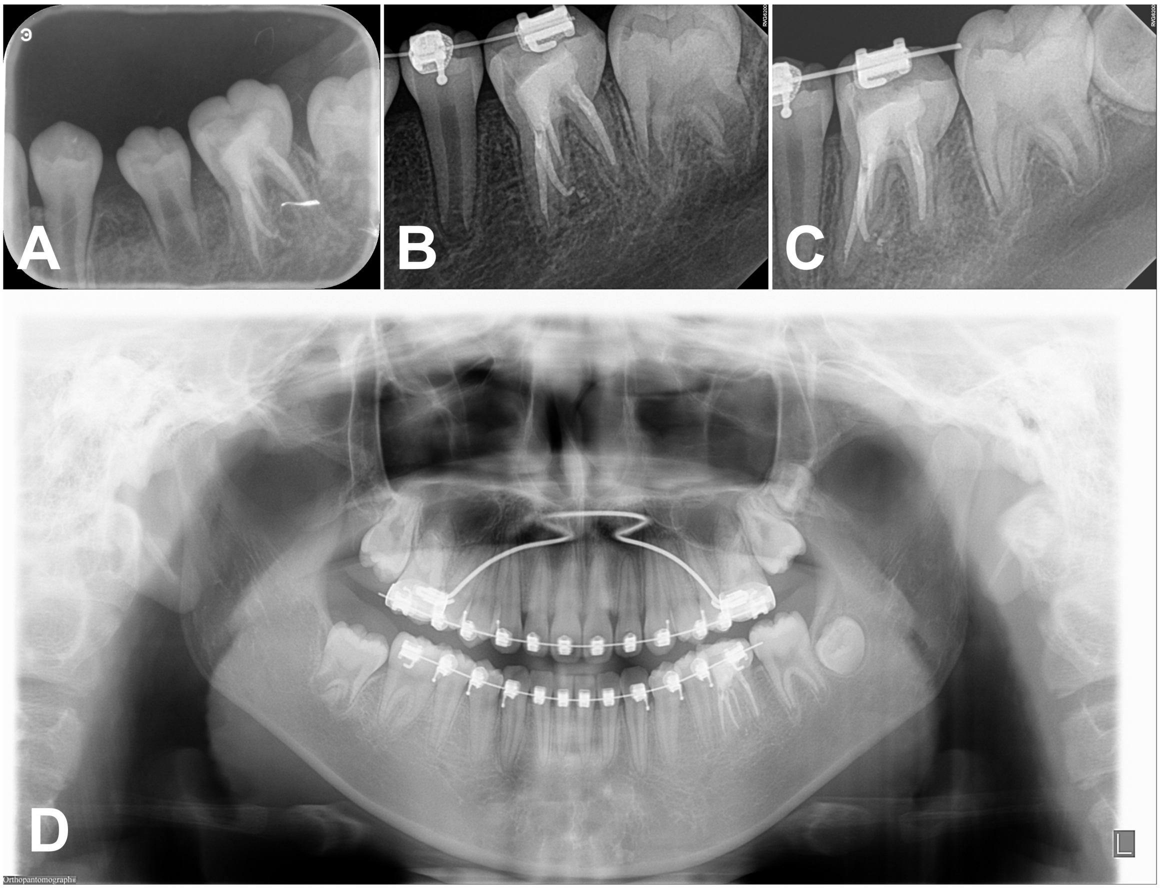

FIGURE 8. Serial postoperative radiographs. Follow-up radiographs: (A) Periapical, 4-month recall. (B) Periapical, 1-year, 2-month recall. (C) Periapical, 3-year recall. (D) Panoramic, 4-year recall. All images demonstrate normal, healed periapical tissue.

requires the absence of pain or inflammation and complete radiographic healing with a normal periodontal ligament space, whereas loose success allows for lesion reduction without full periodontal ligament normalization. All treated teeth remained asymptomatic and functional, with radiographic evidence of lesion resolution or reduction, and were therefore considered to have favorable outcomes.

MIM is characterized by distinctive morphological abnormalities that affect both molars and incisors. Clinically, affected permanent first molars exhibit normal crown morphology but present with abnormally shortened and narrow roots on radiographic examination [10]. These anomalies are frequently bilateral and symmetrical, most commonly involving the permanent maxillary and mandibular first molars as well as the second primary molars [10]. In contrast to systemic dental anomalies such as dentin dysplasia, which affects the entire dentition, MIM represents a localized developmental disturbance. Although epigenetic factors associated with systemic diseases during early childhood disrupt neural development and root formation, the etiology of MIM remains unclear [11–

14]. In this case series, a single patient had a history of premature birth at 7 months of age, suggesting that perinatal systemic stress may contribute to disrupted odontogenesis.

Disruptions during early root development can result in substantial structural irregularities. MIM-affected teeth often display a complex internal anatomy that may complicate root canal treatment. In many cases, the affected teeth develop pulpal necrosis in the absence of identifiable etiological factors such as dental caries, and patients frequently present with apical lesions, swelling, or pain secondary to pulpal necrosis [15]. Therefore, endodontic treatment is essential for resolving the resulting periapical pathology and associated symptoms. However, the prognosis of endodontic therapy is often less favorable when the root morphology is highly irregular. Song *et al.* [16] reported that missed root canals account for approximately 20% of treatment failures. Given that MIM-affected teeth often present aberrant root morphologies and complex canal configurations, the likelihood of undetected canals and non-instrumented spaces is substantially higher, which could ultimately compromise the overall treatment outcomes.

A comprehensive radiographic evaluation is essential for diagnosing MIM and assessing its complex root morphology. However, the structural variability inherent to MIM, together with the limitations of conventional periapical radiographs, often make it difficult to accurately visualize the root canal anatomy, which may compromise treatment outcomes. In such cases, the CBCT provides superior diagnostic information. Unlike conventional imaging, CBCT enables three-dimensional visualization, which is essential for detecting additional canals and delineating complex morphologies [6, 17, 18]. This is particularly important in MIM, which is characterized by cervical mineralized defects (CMDs). As described by Witt *et al.* [1], these defects consist of densely calcified globules within a moderately mineralized matrix, which reduces radiographic contrast and complicates canal identification. The clinical relevance of this limitation is considerable; Kim *et al.* [15] reported that severely calcified canals were present in approximately 52.6% of documented MIM cases. Furthermore, according to the 2025 updated joint position statement from the American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR), intraoperative CBCT imaging is strongly recommended when calcified canals or suspected iatrogenic errors are encountered (Recommendation 2) [6]. In the present case, CBCT imaging was performed in accordance with radiation protection principles, with the patient wearing protective equipment and using the smallest FOV allowed by the imaging system, because the extreme anatomical complexity of the MIM tooth posed a high risk of iatrogenic complications that could adversely affect long-term prognosis. The detailed anatomical information provided by CBCT facilitates safe instrumentation and contributes to the successful completion of nonsurgical root canal treatment.

Despite the favorable outcomes in this case, endodontic treatment is not yet universally accepted for MIM-affected teeth. A consensus on long-term prognosis has not been established, as most previous studies have reported follow-up periods of 1–3 years [19–21]. Furthermore, the inherent challenges of nonsurgical endodontic management in MIM may contribute to clinicians' reluctance to adopt this approach. Although comprehensive long-term data remain scarce, the present cases provide approximately 4–6 years of follow-up data. The treated teeth remained asymptomatic and functional during this period, suggesting a favorable medium-term prognosis. This outcome provides clinically relevant evidence that may help clinicians consider endodontic therapy as a reasonable management option. Further studies are required to establish evidence-based guidelines, including long-term clinical investigations, survival analyses, and evaluation of treatment outcomes across different age groups and severity levels.

Therefore, endodontic treatment should not be considered as the default approach in all cases. Extraction may be more appropriate when the root structure is severely compromised, such as when less than two-thirds of the root remains in patients with a Class II or III sagittal molar relationship or when third molars are present [3]. However, in patients without these risk factors, endodontic treatment may serve as a provisional, yet effective management option.

Although the lengthy and technically demanding endodontic procedures can be challenging for pediatric patients with limited cooperation, our cases suggested that in well-cooperative patients, endodontic treatment may represent a viable therapeutic option with predictable mid-term outcomes. Although root canal treatment is not the only alternative, it may be selectively employed to preserve the tooth and defer more invasive procedures during critical periods of growth and development. However, the broader application of this approach remains limited, as longitudinal studies and long-term clinical data on the prognosis of endodontically treated MIM-affected teeth remain insufficient.

4. Conclusion

Within the limitations of this case series, nonsurgical endodontic treatment may be a viable option for selected MIM-affected teeth. The cases were selected according to predefined clinical, radiographic, and patient-related criteria to minimize selection bias. Specifically, inclusion criteria focused on symptomatic MIM cases in cooperative pediatric patients, with the intent to preserve affected teeth during growth. This treatment should not be considered universally applicable or definitive for all pediatric MIM cases. Instead, nonsurgical endodontic treatment may serve as a growth-preserving or transitional strategy in cases without severe root compromise or unfavorable occlusal conditions. Given the low level of evidence inherent to case series, caution is warranted when generalizing these findings. Further multicenter studies with larger sample sizes and long-term follow-up are needed to establish evidence-based guidelines and determine the long-term prognosis of endodontically treated MIM-affected teeth.

AVAILABILITY OF DATA AND MATERIALS

Data sharing is not applicable to this article, as no datasets were generated or analyzed during the current study.

AUTHOR CONTRIBUTIONS

HJJ and JHH—contributed to study conception, data acquisition, and manuscript drafting. JHH—contributed to the critical revision of the manuscript. Both authors contributed to editorial changes to the manuscript. Both authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was granted exemption from ethical approval and informed consent by the Institutional Review Board of Kyungpook National University Dental Hospital (IRB no: KNUDH-2025-10-02-00).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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