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CASE REPORT

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Nonsurgical endodontic retreatment of C-shaped maxillary molars: case reports and review of literature

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Abstract

The root canal systems of maxillary first molar (MFM) and maxillary second molar (MSM) variations represent a clinical challenge for endodontists, especially the prevalence of fused C-shaped roots. Having a thorough knowledge of root canal configuration is an extremely important point for a successful root canal treatment to avoid missing extra canals. The aim of this article was to present 2 cases of maxillary molar with an unusual C-shaped configuration diagnosed during root canal retreatment/treatment and conduct a literature review of the MFM and MSM anatomy. Case 1 reports that three separate palatal root canals fused into a C-shaped configuration in the MFM, which with an enamel pearl in the furcation, was classified as Type D and first reported in MFM. Case 2 reflects the fusion of all three buccal canals of the MSM into a C-shaped configuration that finally formed an apical foramen with a supernumerary tooth, and the configuration was Type B. Evaluation at an 18-month and a 9-month recall revealed that two patients were symptom-free after the conduct of a non-surgical retreatment/treatment, and the X-ray revealed normal periapical tissue. In addition, the thickness of the Schneiderian membrane due to odontogenic maxillary sinusitis returns to normal after an effective retreatment in case 1. These reports serve to remind endodontists of the importance and complexity of anatomical variations, which should always be considered when formulating an effective root canal treatment plan. The combined use of cone-beam computerized tomography (CBCT) and a dental operating microscope (DOM) will be profitable to locate and identify extra canals when a periapical radiograph shows signs of an unusual canal morphology.

Keywords Maxillary molar, C-shaped, Fused root, Enamel pear, Root canal treatment, Supernumerary tooth

Introduction

The main cause of endodontic treatment failure is the inadequate understanding of the root canal configuration and undetected extra root canals [1]. Conversely, a successful root canal treatment depends on a clear understanding of the root canal system with its frequent variations [2]. Nonsurgical root canal retreatment appears to be the best solution to deal with a complex tooth anatomy [3]. Therefore, anticipation possible anatomic variations and a reasonable treatment strategy are essential to reduce treatment failure and enhance the success rate of root canal treatment. Maxillary first molar (MFM) and maxillary

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second molar (MSM), which have the rearward anatomical position of the molar and limited view, are a huge challenge in root canal treatment for the endodontists. Furthermore, the complexity and variation of root canal systems are the major reasons for treatment failure [4].

The most common MFM and MSM are described as teeth with 3 roots and 3 or 4 canals, including a mesiobuccal (MB) root with 1 or 2 canals and distobuccal (DB) and palatal (P) roots with a single canal each [5, 6]. Additional anatomic variations of the maxillary molars have been reported in the literature. Badole et al. [2] in 2014 reported 7 root canals distributed within 3 roots in the MFM (3 in the MB root, 2 in the DB root, and 2 in the P root). In the same year, Rouhani et al. [7] found 4 separate roots in MFMs in Iranian population. Ozcan et al. [8] reported 3 mesiobuccal canals in MSM. Compared with maxillary second molars (MSMs), the incidence of MFM root fusion was lower, at 1.38%-21% [9, 10] and the prevalence of C-shaped canals was 1.1%-8.3% [10, 11] in MFMs with fused roots, which was 10.6%- 62.3% and 5.1%-22% in MSMs [4], respectively.

The case reports present an uncommon anatomy and retreatment/treatment of MFM and MSM with C-sharped canal configurations. The morphological variation, failure of root canal treatment and posterior location provide challenges for endodontists in performing retreatment/treatment.

Case presentation

Case 1

A 33-year-old male patient with no significant medical history was referred for root canal retreatment on tooth #26 because of severe toothache in the tooth during mastication in the past three months. Six months ago, the patient had a history of root canal treatment of tooth #26 because of irreversible pulpitis. Clinical examination revealed the tooth was sealed with a composite resin filling material, tenderness to percussion and no response to cold and electric pulp test. Periodontal pockets and tooth mobility were within normal limits. Radiographic examination showed incomplete root canal fillings in the three obturated canals and extra canals were suspected (Fig. 1A). An apparent cylindrical root was observed in the furcation region (Fig. 1A). To demonstrate the unusual root canal configuration and locate extra canals, a CBCT (New Tom, NNT) scan was recommended with the patient's informed consent. CBCT scanning images (Fig. 2A-E) and 3-dimensional (3D) reconstruction images (Fig. 2F) were taken. They showed the presence of 3 roots and 5 canals; specifically, there was a fused C-shaped P root with 3 canals, mesiopalatal (MP), palatal (P) and distopalatal (DP), MB and DB roots each with a single canal in each root, which revealed that there were inappropriate root canal fillings in MB, DB and distopalatal (DP) canals in previous treatment and two non-treated P (MP and P) canals (Fig. 2B). A cylindrical enamel pearl (EP) was observed in the furcation area, surrounded by the semilunar shape of the P root (Fig. 2B

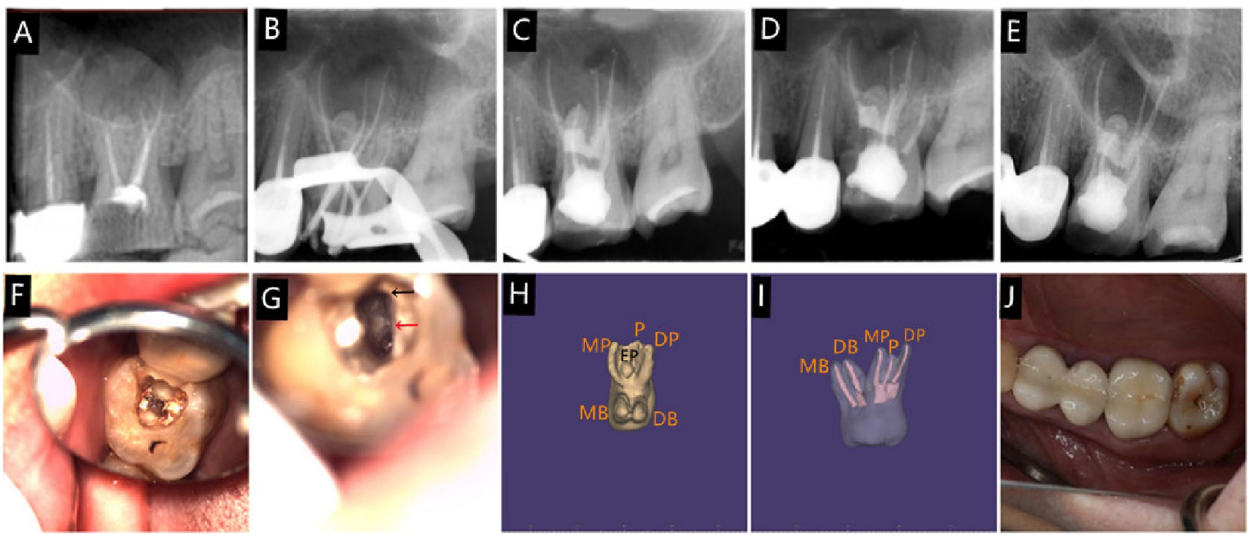

Fig. 1 **A** A preoperative periapical radiograph of tooth #26; **B** The master apical cone periapical radiographs; **C** The obturation periapical radiograph; **D** Three-month follow-up; **E** Six-month follow-up; **F** Pulp cavity after removing filling material: **G** Pulp cavity after removing mesial roof of the pulp chamber; black arrow represents the mesio-palatal canal orifice;red arrow represents the palatal canal orifice. **H-I** The 3D reconstruction of tooth #26 showing three roots (one C-shaped palatal root, one MB root and one DB root) and an EP; **J** Crown over tooth #26

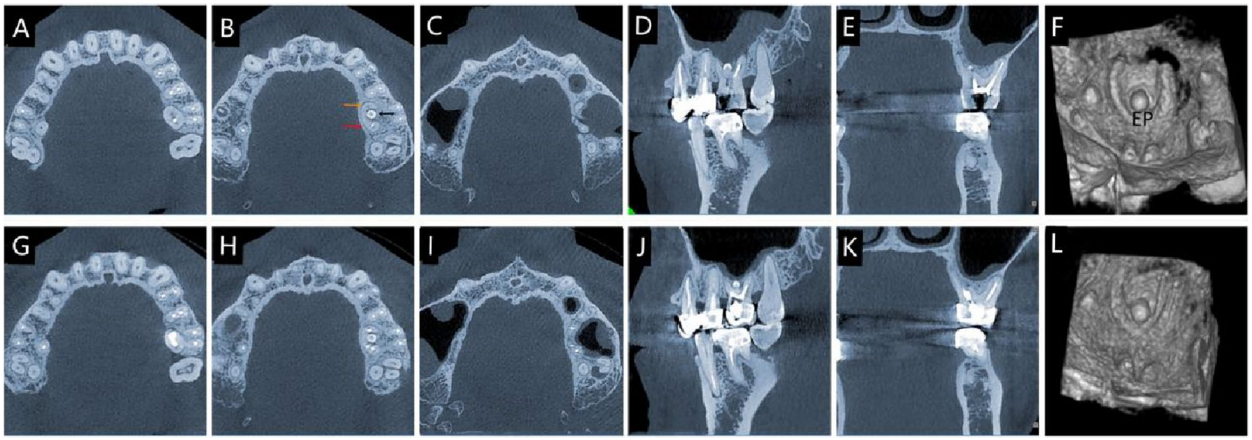

Fig. 2 **A**-**C** CBCT axial views (coronal third, middle third, and apical third), orange arrow represents the mesio-palatal canal; red arrow represents the palatal canal; **D-E** CBCT sagittal and coronal view: left maxillary sinus membrane thickening; **F** The 3D reconstruction of tooth #26 showing periodontal bone loss; **G-I** One-year recall CBCT axial views (coronal third, middle third, and apical third); **J-K** One year recall CBCT sagittal and coronal view: left maxillary sinus membrane return to normal level; **L** The one year recall 3D reconstruction of #26 showing periodontal bone renew

and F). 3D reconstruction images showed the destruction of periapical tissue in tooth #26 (Fig. 2F). The CBCT sagittal and coronal view revealed the mucosa in the left maxillary sinus severely thickened (Fig. 2D, E). According to clinical and radiographic findings, a diagnosis of symptomatic apical periodontitis and suspected maxillary sinusitis was made for tooth #26. A non-surgical endodontic retreatment was planned, and the patient consented.

Local anaesthesia was achieved, using 4% articaine containing 1:100000 epinephrine, before a rubber dam was placed on the tooth. After removing the filling material, three obturated root canals (MB, DB and DP) were revealed (Fig. 1F). Examination was performed using a DOM (Leica AG, Heerbrugg, Switzerland), MP orifice was found (Fig. 1G). With the help of CBCT images and DG-16 endodontic explorer (Hu-Friedy, Chicago, IL, USA), a fifth root canal orifice (P) was located in the gorge area of the C-shaped configuration which was closer to MP (Fig. 1G).

Removal of gutta-percha was achieved by retreatment files (VDW, Munich, Germany). A size #6 K-file (Dentsply, Maillefer, Ballaigues, Switzerland) was precurved to negotiate the MP and P canals. The working length of all the canals was determined to be 21 mm for MP, DP, and P, and 15 mm for MB and DB using an apex locator (Raypex 2; VDW, Munich, Germany). Root canal preparation and shaping were performed using the crown-down technique, followed by the sequential use of nickel-titanium ProTaper Gold rotary files (Dentsply Sirona, Ballaigues, Switzerland). The speed and torque values of the files were set according to the manufacturer's recommendations. First, the SX, S1, and S2 files were used for initial root canal shaping, primarily for the coronal and middle sections of the canals. Then, the lower sections were prepared with the finishing file F2 to a #25/0.06 taper. Master cones (Dentsply Maillefer) were selected to match the working length, which was confirmed radiographically (Fig. 1B).

Sodium hypochlorite(Naocl, 2.5%) and 17% Ethylenediamine-tetra-acetic acid (EDTA, 17%) coupled with ultrasonic irrigation were performed. After drying the canals with paper points, all canals were medicated with calcium hydroxide ($Ca(OH)_2$) and sealed with glass ionomer cements (3 M ESPE, Luting Cement, Germany). After one week, the patient was asymptomatic with no tenderness to percussion. After irrigating with NaOCl (2.5%), the canals were obturated using the continuous wave obturation technique with warm gutta-percha and vertical compaction (Elements Gutta Percha Cartridge, SybronEndo, CA 91740, USA). iRoot SP (Root Canal Sealing Material, Henry Schein, Canada) was used as the sealer cement to ensure complete filling of the entire root canal (Fig. 1C). The tooth was then restored with composite resin (P60; 3 M Dental Products, St. Paul, MN, USA). The patient was asymptomatic at the three-month and six-month follow-up (Fig. 1D and E). The tooth #26 was restored with a full ceramic crown (Fig. 1J). After one year, CBCT images were acquired to plan orthodontic treatment (Fig. 1G-K). Treated tooth #26 showed that the that the lamina dura surrounding the root was intact (Fig. 1L); in addition, the sagittal and coronal view showed a significant reduction of the Schneiderian membrane thickness (Fig. 1J, K).

Case 2

A 24-year-old female patient was referred for root canal treatment on tooth #27 because of redness and swelling of palatal mucous in the past week. Three years ago, the patient had a history of filling treatment of tooth #27. The medical history was noncontributory. Clinical examination revealed one extra cusp was detected on the buccal aspect of the tooth #27 and a composite resin filling covered the occlusal and buccal surfaces with secondary caries and a sinus track on the palatal aspect (Fig. 3A-C), tenderness to percussion and no response to cold and electric pulp test. Periodontal pockets and tooth mobility were within normal limits. The Radiographic examination showed the sinus tract originated from tooth #27 and periapical radiolucency was present at the apexes (Fig. 3D). CBCT was performed after obtaining consent from the patient. The CBCT axial images revealed a C-shaped canal morphology fused with MB root, DB root and the root of supernumerary tooth merged into one orifice and the destruction of periapical tissue in tooth #27 (Fig. 3E-G). The CBCT coronal view revealed the supernumerary tooth fused with tooth #27 (Fig. 3H). According to the clinical and radiographic findings, a diagnosis of symptomatic apical periodontitis was made for tooth #27. A non-surgical endodontic retreatment was planned, and the patient consented.

Local anaesthesia was achieved using 4% articaine containing 1:100,000 epinephrine, and a rubber dam was placed on the tooth. After removing the filling material, two access openings were done carefully. To gain sufficient access to the root canals, the access cavity of tooth #27 was widened mesiodistally. The DB canal was located first, followed by the MB canal, using a DOM and a DG-16 endodontic explorer. Since the MB2 canal was hidden under a dentinal shelf, it was difficult to find. Therefore, the access cavity was again widened in the mesial orientation and the MB2 canal was explored using a pre-curved #6 K-file. The same steps as in case 1 were performed in working length determination and root canal preparation (Fig. 4G). The MB, MB2, DB, and P canals of tooth #27 were instrumented to F2 (#25/0.06), while the canal of the supernumerary tooth was instrumented to #50/0.06. Master cones were then confirmed by a periapical radiograph (Fig. 4A). Due to the continuous root canal system between tooth #27 and supernumerary tooth, the interlayers of the root canals between MB, DB of tooth #27 and supernumerary tooth were removed by an ultrasonic tip to reveal the absorbed apical foramen, forming a C-shaped configuration (Fig. 4H). Then, matching the working length was carried out again (Figure B).

All root canals were irrigated, dried, medicated with calcium hydroxide, and sealed as in Case 1. One week later, the absorbed apical foramen was sealed with iRoot BP (Root Repair Material, Henry Schein, Canada) (Fig. 4C, I). One day later, the C-shaped configuration

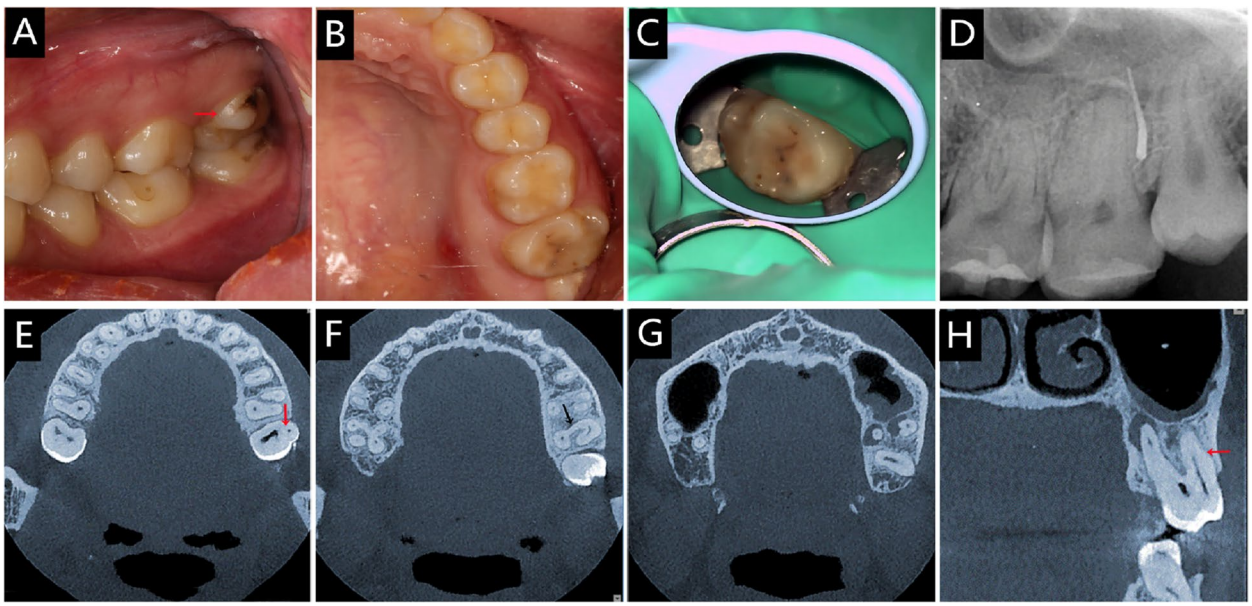

Fig. 3 **A** The buccal view of tooth # 27, red arrow represents the supernumerary tooth; **B-C** The tooth was sealed with composite resin and caries around the composite resin filling margin; **D** A preoperative periapical radiograph of tooth #27; **E**–**G** CBCT axial views (coronal third, middle third, and apical third), red arrow represents the supernumerary tooth, black arrow represents MB2; **E** CBCT coronal view: red arrow represent the supernumerary tooth

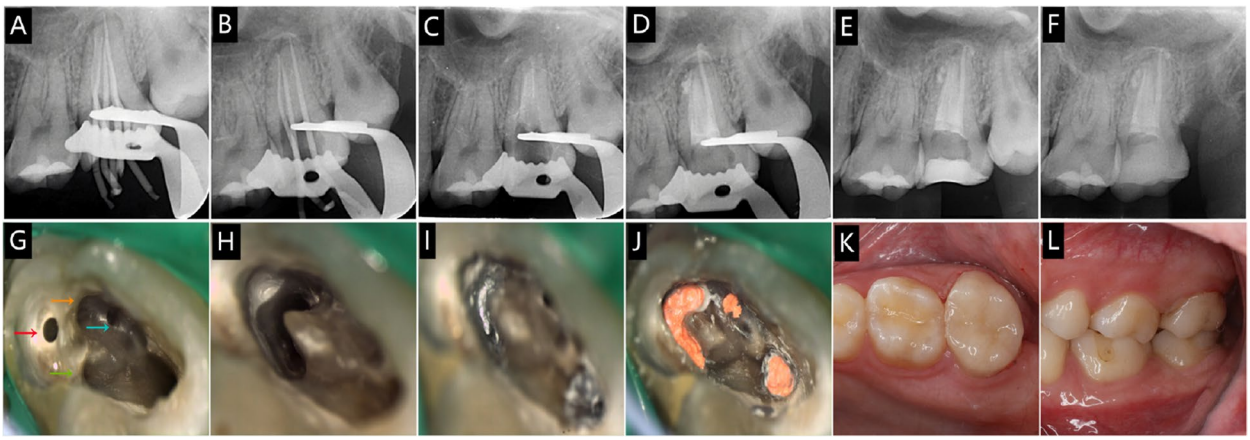

Fig. 4 **A-B** The master apical cone periapical radiographs; **C** Distobuccal apex was sealed with iRoot BP; **D** The obturation periapical radiograph; **E** Four-month follow-up; **F** Nine-month follow-up; **G** Pulp cavity after preparation, red arrow for supernumerary tooth, orange for MB, bule for MB2, green for DB; **H** Pulp cavity after removing the interlayers of MB, DB and the supernumerary tooth; **I** iRoot BP in the distobuccal root canal (the white filling material); **J** Pulp cavity after root canal filling; **K-L** Onlay over tooth #27

was backfilled with warm gutta-percha. The MB2 and P canals were obturated using the continuous wave obturation technique, after which the tooth was restored with composite resin, as in Case 1 (Fig. 4D, J). The patient was asymptomatic at the 4-month and 9-month follow-up (Fig. 4E, F). The tooth #27 was restored with an all-ceramic onlay (Fig. 4K, L).

Discussion

Although root fusion is most commonly found in mandibular molars [12], its presence was reported in maxillary first and second molars [13, 14]. Currently, fusion less frequently occurs in MFMs than in MSMs [15], which may be the reason for the fewer case reports of MFMs. It was reported that the prevalence of root fusion in MFMs and MSMs was 1.38% and 23.9% in China [9], respectively, 7% and 21% in Saudi Arabian [10], respectively. Moreover, females had 3.4 times higher chance to present fused roots than males. It means that molar fused root presents sex-associated differences, in which females are more affected than males [16]. Moreover, it is the probable cause for the observed variations in root fusion between the genders.

Newton and McDonald [17] were the first authors to describe a C-shaped configuration fused between MB and DB roots. In 2016, Martins JN performed a CBCT analysis of 2227 upper molars and classified the C-shaped configuration into five categories according to which roots were fused [18]. As documented in the literature, only 16 articles (13 for MFMs, 3 for MSMs), including the case report presented in this article, reporting 21 cases (16 for MFMs, 5 for MSMs), describe the C-shaped canal of MFMs and MSMs. The pertinent details regarding these cases were compiled in Tables 1 and 2. Type A, fusion between the MB and P roots; Type B, fusion between MB and DB was reported in 7 of the reported case reports (including our case report 2) [19–24]; Type C, the fusion between the DB and P roots, has also been observed in 7 reported cases [4, 17, 21, 25–27]. Type D, characterized by the presence of a large P root canal or the fusion of 2 P roots, has 3 reported cases in the current literature, including Case 1 [28, 29]. And Type E, fusion of 3 roots, has 3 typical cases that have been reported [25, 30, 31]. The prevalence for MFMs [18] was 0.1%, 0.1%, 0.9% for Type A, Type B and Type C, respectively. Type D and E were not found in the MFMs from the sample. The prevalence for MSMs [18] was 0.5%, 2.1%, 0.2%, 0.1%, and 1.0% for each type, respectively. From the available literature, it was shown that Type B is a more common condition in MSMs. Case 1 reports a very rare MFM with a C-shaped P canal (three P root canals, with one independent apical foramen each, fused into a C-shaped configuration), which is the first case report of Type D in the MFMs based on past case reports.

Moreover, it was reported that the bilateral symmetry of C-shaped canals of MFMs and MSMs ranged from1.27% [6] to 13% [9]. Chen et al. [32] reported that bilateral symmetry of roots and root canals of MFMs was present in 2.0% of the Eastern Chinese individuals. Zhang et al. [33] reported that bilateral symmetry of MSMs was up to 84.0% of the Chinese population. The reason for this consequence may be related to ethnic variations and the sample size. However, bilateral symmetry was found in Table 1, which is similar between right- and left-side teeth in the same patient [25].

Table 1 Summary of the case reports with C-shaped canals in maxillary first molars and maxillary second molars

Reference	Teeth	Age & sex	No. of canals	Location of the C-shaped canal	Other canals	Type
Newton (1984) [17]	MFM	37/M	2	Fusion between DB and P canals	MB	C
Dankner (1990) [26]	MFM	11/F	3	Fusion between DB and P canals	MB MP	C
De Moor (2002) [27]						
Case 1	MFM	44/F	3	Fusion between DB and P canals	MB MP	C
Case 2	MFM	21/M	2	Fusion between DB and P canals	MB	C
Yilmaz (2006) [19]	MFM	28/F	2	Fusion between MB and DB canals	P	B
Kottoor (2011) [28]	MFM	42/M	4	Fusion between 2 p canals	MB, DB	D
Karanxha (2012) [20]	MFM	26/F	4	Fusion among 2 MB and DB canals	P	B
Martins (2013) [21]						
Case1	MFM	39/M	2	Fusion between DB and P canals	MB	C
Case2	MFM	67/F	2	Fusion between MB and DB canals	P	B
Joshi (2014) [30]	MFM	24/F	2	Fusion between B and P canals		E
Paksefat (2014) [22]	MFM	27/F	4	Fusion between MB and DB canals	MB2, P	B
Kharouf (2019) [25]	MFM	13/F				
Right			2	Fusion between B and P canals		E
Left			3	Fusion between DB and P canals	MB	C
Liu CH (2021) [23]	MFM	50/M	4	Fusion among 2 MB and DB canals	P	B
Liu H (2024) [31]	MFM	23/F	5	Fusion among 2 MB, 2DB and P canals		E
Present study case 1	MFM	33 M	5	Fusion among 3 P canals	MB DB	D
Singla (2010) [29]	MSM	36/F	3	Fusion between 2 P canals	MB DB	D
Lopes (2016) [24]	MSM	50/F	2	Fusion between MB and DB canals	P	B
Sun ZA (2022) [4]						
Case 1	MSM	26/F	3	Fusion between 2 P canals	MB DB	D
Case 2	MSM	32/F	2	Fusion between DB and P canals	MB	C
Present study case 2	MSM	24/F	2	Fusion among 2 MB and DB	P	B

MB mesiobuccal, *DB* distobuccal, *P* palatal, *MP* mesiopalatal, *F* female, *M* male, *MSM* maxillary first molar, *MSM* maxillary second molar

Table 2 Summary of the types of pulp chamber anatomies found on the case reports

	Type B	Type C	Type D	Type E
				
	Fusion between MB and DB	Fusion between DB and P	Fusion between 2 P or more	Fusion among MB, DB and P
Reference	Yilmaz (2006) [19] Karanxha (2012) [20] Martins (2013) [21] Case 2 Paksefat (2014) [22] Liu C (2021) [23] Lopes (2016) [24] Present study case 2	Newton (1984) [17] Dankner (1990) [26] De Moor (2002) [27] Two cases Martins (2013) [21] Case 1 Kharouf (2019) [25] Left one Sun ZA (2022) [4] Case 2	Kottoor (2011) [28] Singla (2010) [29] Present study case 1	Kharouf (2019) [25] Right one Joshi (2014) [30] Liu H (2024) [31]

MB mesiobuccal, *DB* distobuccal, *P* palatal

Furthermore, all the cases described in Table 1 involved gender. It was reported that [6] the occurrence of C-shaped configurations in MFMs and MSMs was higher in females than in males, and Table 1 also confirmed this conclusion.

Root canal variations in MFMs and MSMs could be divided into number variations and anatomical variations, which represents a challenge to both endodontic diagnosis and treatment. The most common variation in MFMs and MSMs is the presence of extra root

canals, which were observed in 63.59% to 91.0% of mesiobuccal roots, 1.12% to1.8% of distobuccal roots, and 0.7%-1.76 of palatal roots [9, 14, 34–36]. Olczak et al. [37] reported that men possess a high prevalence of extra root canals compared with women. The incidence of fused roots in MFMs from a native Chinese population has been reported to be as low as 2.17% [36]. The C-shaped root is one type of root fusion, which represents a prevalence of 1.1% in MFMs and 3.8% in MSMs [18]. Although the incidence of the variations is not common, their importance should not be ignored. The endodontists must possess knowledge not only of the intricate anatomical structure of MFMs and MSMs, but also the superimposition over another canal and bony structures -such as maxillary tuberosity on radiographs complicate the detection of extra canals and supernumerary tooth [38, 39]. Failure to identify and treat extra canals is a major cause of unsuccessful treatment [40]. When root canal retreatment is needed, a careful X-ray evaluation of the first root canal treatment should be essential for the identification of possible root canal variations prior to retreatment. In the present case 1, the appearance of multiple overlapping images of pericementum indicated the possibility of extra canals in the primary X-rays. CBCT is widely used to detect morphological variations and extra canals of tooth by providing 3D images [41]. In the cases, an EP (3.2 mm × 2 mm) composed of enamel only in the furcation area and a supernumerary tooth on the buccal of tooth #27 were detected by CBCT, which did not lead to periodontal disease. In addition, in case 1, inflammatory hyperplasia of the maxillary sinus mucosa was found, indicating suspected maxillary sinusitis. Once extra canals and unusual anatomy were suspected, the DOM, with the better illumination and higher magnification, make it easy for locating root canal orifices, preferably combining with ultrasonic tips and endodontic explorer [4, 39]. Exploring along the development groove on the pulp chamber floor with ultrasonic tips and endodontic explorer was applied to maximize the root canal location [42]. Furthermore, it is widely reported that the combined use of DOM and CBCT images significantly enhanced the success rate of root canal retreatment/treatment [43, 44].

Conclusion

The two cases reports present the unusual anatomy of the MFM and the MSM with C-shaped canal configurations, respectively. Adequate knowledge of root canal variation is a basic requirement for endodontists during root canal treatment. Extra root canals and persistent bacterial infection should be considered as important factors that may influence the continuation or development of post-treatment disease. C-shaped root canals greatly complicate the morphology. The application of CBCT and DOM greatly improves the visualization of root canal treatment, providing diagnostic and therapeutic ideas and technical support for the retreatment/treatment of variant root canals.

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Authors' contributions
Ming Liu: Conceptualization, writing—original draft; Yanling Huang: Data curation, formal analysis; Yixuan Wu: Investigation, data curation; Yi Zhang: Methodology, writing—review and editing; Zhisheng Zhang: Supervision during revising manuscript; Qianju Wu: Conceptualization, methodology, writing – review and editing, project administration. All authors have read and agreed to the published version of the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The clinical operation involved in this case was told to the patients and got the informed consent from the patients and totally approved by the Ethics Committee of Stomatological Hospital of Xiamen Medical College. All authors and patients have read and agreed to the published version of the manuscript.

Consent for publication
Written informed consent from patient has been taken. All authors and patients have read and agreed to the published version of the manuscript.

Competing interests
The authors declare no competing interests.

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