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CASE REPORTS

Endodontic management of maxillary permanent molar C-shaped morphology

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ABSTRACT

Aim: *Report on the successful endodontic management of four permanent maxillary molars with a C-shape configuration of the root canal system.*
Summary: *Even though C-shaped anatomies are more commonly described in the mandibular molars, its occurrence in permanent maxillary molars has also been reported. Complexity of the root canal system may pose a difficulty in achieving proper chemo-mechanical debridement, and consequently jeopardize the success of endodontic therapy. Additional dedicated armamentarium can help the clinician recognize, assess, plan and better manage such complex configurations.*
Key learning points

- *Although of rare prevalence, clinicians must be aware and recognize the possible existence of a C-shaped root canal configuration in both first and second permanent maxillary molars.*
- *This anatomy can be attributed to an embryologic alteration that leads to the non-division of roots during the root formation stage of tooth formation.*
- *Further studies on the prevalence of the C-shaped configuration in permanent maxillary molars may contribute to a better understanding and, consequently, proper management of this morphology.*
- *Specific tools, such as the dental operating microscope and specific ultrasonic tips, as well as additional means of enhancing chemical debridement, are essential for the correct management of these intricate anatomies and appear to positively impact outcome of root canal treatment.*

KEYWORDS *anatomy, C-shape, endodontics, maxillar molar*

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Introduction

A proper mechanical debridement and disinfection of the root canal system are two of the most important aspects when aiming for a successful endodontic treatment procedure (1). Prior knowledge of the most common configurations and possible variations of the teeth's internal anatomy is mandatory to optimize the cleaning and shaping procedures, which ultimately may increase the chance of positive outcomes (2). Although the C-shaped root canal configuration has been well documented for several groups of teeth, it is more commonly found in the mandibular second molar, in which it may reach a prevalence of 44.5% in East Asian populations (3). This morphology in maxillary permanent molars, although uncommon, has been described as far back as in 1984 (4). In these teeth, this anatomic configuration may present a proportion that may be as high as 1.1% and 3.8% for maxillary first and second molars (5), respectively. Complementary to the few prevalence studies on this anatomy (5, 6) a few case reports have also been documented (4, 7, 8) that are quite variable in their characteristics. The location, number and course of the main root canals in C-shaped permanent maxillary molars may prove a challenge for the instrumentation and disinfection of the canal system. More complex morphologies may lead to unidentified canals during root canal treatment procedures, which have been linked to persistence of periapical pathology on endodontically treated teeth (9). Moreover, canals with such morphologies exhibit large areas of untouched canal areas following preparation (10), which, especially in infected cases, may result in insufficient disruption of the bacterial load to levels compatible with periapical health.

The aim of the present case series is to present four cases of successful endodontic treatments performed on maxillary permanent molars presenting a C-shaped root canal configuration.

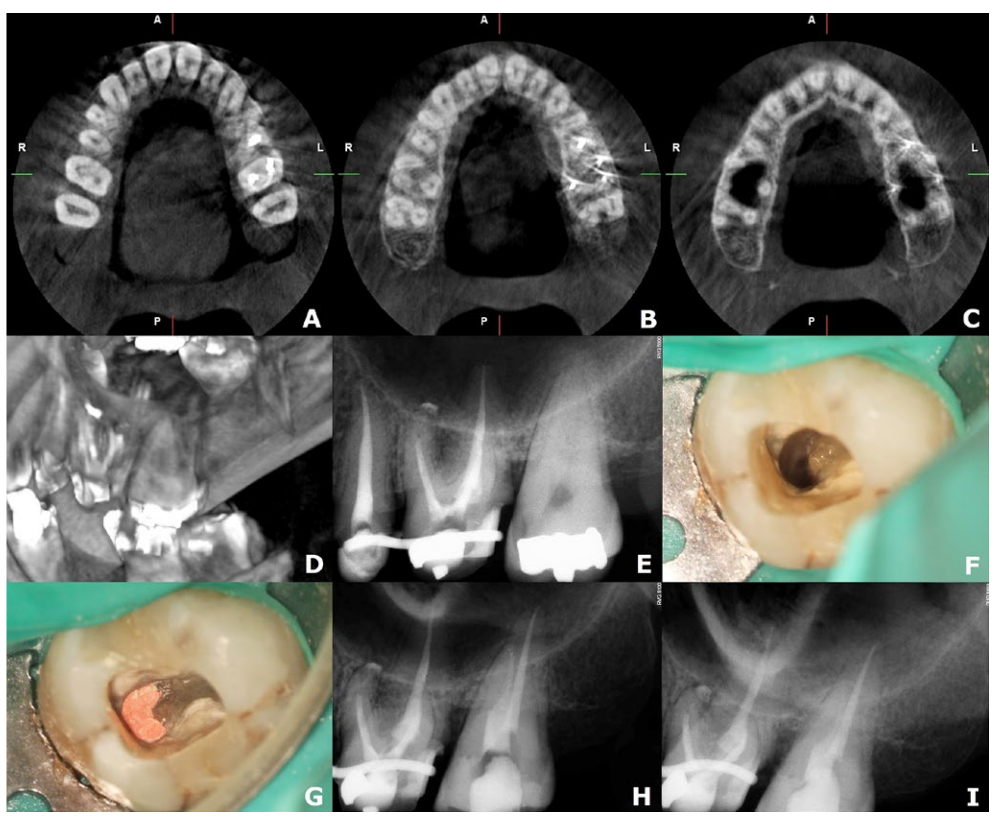

Figure 1. **A)** CBCT axial view, coronal third. **B)** CBCT axial view, middle third of the root of tooth 27 shows a large buccal root canal. **C)** CBCT axial view, apical third. **D)** CBCT 3D reconstruction, a large buccal root can be observed instead of the typical two buccal roots. **E)** Initial periapical radiograph, where two superimposed conical roots can be observed. **F)** A buccal C-shaped canal orifice can be observed in the pulp chamber floor. **G)** Obturation of the C-shaped root canal. **H)** Final radiograph of the root canal treatment. **I)** Eight months recall.

Case reports

General clinical procedures
All patients were referred for endodontic evaluation at private practices. In all cases the medical and dental history was reviewed and considered non-contributory, and an intra-oral and radiographic examination was performed. Periodontal pockets and mobility were within the physiological limits for all teeth considered. Diagnosis of pulpal and periapical pathosis was made based on pulpal tests and periapical radiographs. Root canal therapy was recommended and accepted by all patients. After local infiltration (Artinibsa, Inibsa, Barcelona, Spain) and rubber dam placement, access was obtained under dental operating microscope magnification, using round burs (Komet Medical, Rösrath, Germany; R&S, Tremblay-en-France, France) or Start X ultrasonic tips (Dentsply Maillefer, Baillagues, Switzerland) or both. A full debridement was performed under copious irrigation with 5.25% sodium hypochlorite (Denta Flux, J. Ripoll SL, Madrid, Spain). Working length was established using electronic apex locators (Root ZX II, Morita, Komuro, Japan; or Propex Pixi, Dentsply Maillefer, Baillagues, Switzerland). In all cases, the final irrigation procedures included also a 17% EDTA (EDTA, Laboratorios Clarben S.A., Madrid, Spain), one-minute irrigation prior to a final sodium hypochlorite rinse under ultrasonic activation (Irri K, VDW GmbH, Munich, Germany). After canal obturation with a vertical condensation technique with gutta percha and a resin based root canal sealer (AH Plus, Dentsply DeTrey, Konstanz, Germany), intra-coronal sealing was performed with Ionoseal (VOCO GmbH, Cuxhaven, Germany) and the teeth were provisionally restored with Cavit (Cavit W, 3M ESPE, Seefeld, Germany). All cases were sent to the referring dentist for the direct definitive restoration of the access cavity after the endodontic treatment was completed. A posterior follow-up appointment was able to show an improvement of the clinical condition of all cases.

Case #1
A 39-year-old Caucasian female was referred for evaluation of tooth 27 (maxillary left second molar). Her chief complaint was spontaneous pain and increasing pain to temperature variations. The radiographic analysis revealed a secondary carious lesion on tooth 27. The diagnosis was irreversible pulpitis with normal periapical tissues. After the occlusal amalgam filling was removed and the carious lesion was excavated, access to the pulp chamber was achieved and a pre-endodontic resin restoration was built to avoid leakage. Upon examination of the pulp chamber floor two canals were easily identified; a semi-lunar shape buccal canal orifice, surrounded by developmental grooves, and a palatal canal (Figure 1F). A previously obtained CBCT scan confirmed the diagnosis of a maxillary second molar C-shaped B1 configuration (Figures 1A to 1D). Mechanical instrumentation was performed with Protaper Universal NiTi rotary files (ProTaper Universal, Dentsply Maillefer, Baillagues, Switzerland) using recommendations by the manufacturer. The developmental groove and the coronal portion of the C-shaped root canal was also cleaned using a #3 ProUltra ultrasonic tip (ProUltra, Dentspy Maillefer, Baillagues, Switzerland) and obturated (Figure 1G and 1H). At the 8 months recall the tooth showed no clinical or radiographic findings (Figure 1I).

Case #2
A 31-year-old Caucasian female was referred for endodontic treatment with a chief complaint of spontaneous pain and pain upon mastication in the maxillary right quadrant. Clinical examination revealed tenderness to percussion on tooth 17 (maxillary right second molar). The radiographic examination showed a previous single root canal filling in what appeared to be a single root (Figure 2F). A diagnosis of previously treated tooth with symptomatic apical periodontitis was made. After access, a large C-shaped distopalatal canal connected by a developmental groove to an independent

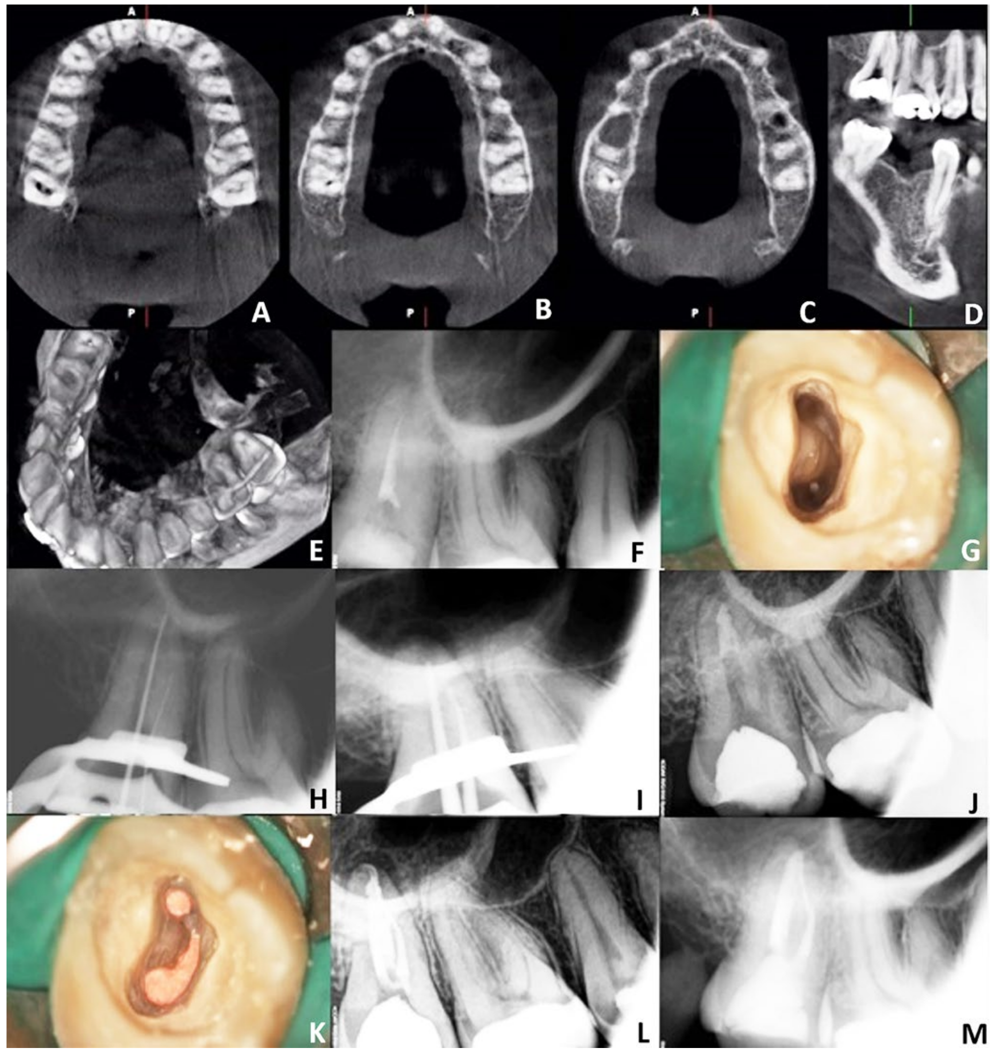

Figure 2.
A) CBCT axial view, coronal third. **B)** CBCT axial view, middle third of the root. A complete fusion of the roots of tooth 17, with two root canals can be observed. **C)** CBCT axial view, apical third. Both canals merge together. **D)** CBCT sagittal view. **E)** CBCT 3D reconstruction, where fusion of the three roots of tooth 17 is observed. **F)** Initial periapical radiograph. A large single root is displayed in the tooth 17. **G)** C-shaped root canal configuration. **H)** Working length radiograph of distopalatal canal and ledge of the mesiobuccal canal. **I)** Cone fit radiograph after successfully managing the ledge in the mesiobuccal canal. **J)** Radiographic assessment of MTA plug in distoplatal canal. **K)** Obturation of the C-shaped root canal. **L)** Final radiograph of the root canal treatment. **M)** Ten months recall.

mesiobuccal canal (Figure 2G) was observed, which corresponds to an E2 morphology. The prior treatment had created a large ledge in the mesiobuccal root canal. A diagnostic CBCT scan was taken in between visits which revealed that this mesiobuccal canal merged apically with the C-shaped distopalatal canal (Figures 2A to 2E). The pre existing ledge was successfully negotiated, but created a significant platform that can be seen in the final obturation radiograph (Figures 2H, 2I and 2L). Canals were mechanically instrumented with Protaper Universal NiTi rotary files (ProTaper Universal, Dentsply Maillefer, Baillagues, Switzerland) according to the manufacturer's recommendations. The C-shaped distopalatal root canal was sealed with a ProRoot MTA apical barrier (ProRoot MTA, Dentsply Tulsa, Tulsa, USA) (Figure 2J) and subsequently obturated with gutta-percha and sealer (Figure 2K). The 10 months recall radiograph showed complete periapical healing (Figure 2M).

Case #3

A 53-year-old Caucasian male was referred with a chief complaint of spontaneous pain and increasing pain to temperature variations in the maxillary left quadrant. A clinical observation detected an amalgam filling on the occlusal surface of tooth 27 (maxillary left second molar). The reaction to the ice sensibility test was intense pain that lingered for

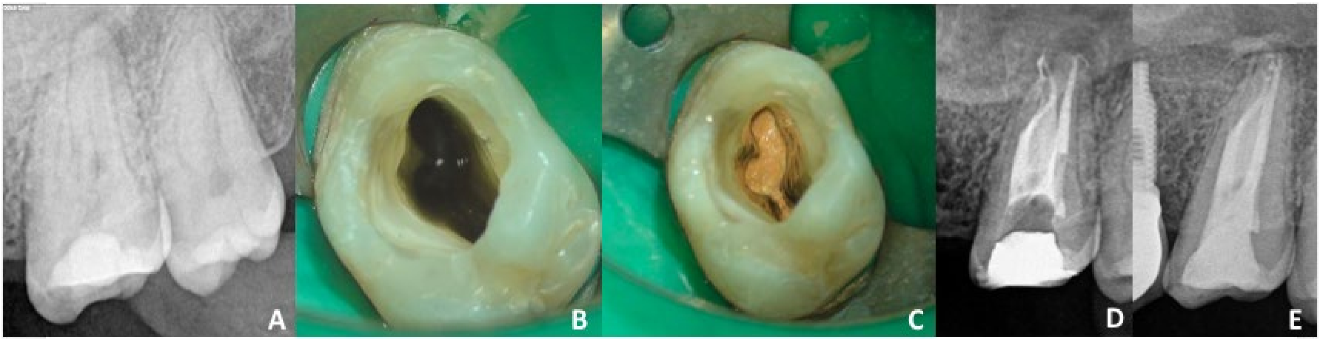

Figure 3.
A) Initial periapical radiograph of tooth 27, with periapical lesion and what appear to be two roots.
B) Pulp Chamber floor after endondontic access, C-shaped root canal configuration. Two canals could be identified: one palatal canal, and fused distobuccal and mesiobuccal canals, forming a buccally faced semi-lunar shape.
C) Obturation of the C-shaped root canal.
D) Final radiograph of the root canal treatment.
E) Nine years recall.

several minutes, with no alterations to percussion nor palpation. The periapical radiography (Figure 3A) showed alteration of the periapical tissues. The diagnosis was irreversible pulpitis with asymptomatic apical periodontitis. After removing the occlusal filling and achieving access to the pulp chamber, two canals could be identified: one palatal canal, and fused distobuccal and mesiobuccal canals, forming a buccally faced semi-lunar shape, corresponding to a B2 configuration (Figure 3B). Mechanical instrumentation was performed with Protaper Next NiTi rotary files (ProTaper, Dentsply Maillefer, Baillagues, Switzerland) using recommendations by the manufacturer. The developmental groove and the coronal portion of the C-shaped root canal was also cleaned using a #3 Start-X ultrasonic tip (Start-X, Dentspy Maillefer, Baillagues, Switzerland) and filled (Fig. 3C and D). A recall appointment 9 years after treatment revealed absence of symptoms and the periapical radiography showed resolution of periapical pathosis (Figure 3E).

Case #4

A 54-year-old Caucasian female was referred for endodontic treatment of tooth 16 (maxillary right first molar). There was no response to the cold sensibility test, and there was tenderness to vertical percussion. Periapical radiography showed apical radiolucency (Figure 4A), and the diagnosis of necrotic pulp and symptomatic apical periodontitis was established. Access was done through the existing rehabilitation, and two large distopalatal and mesiobuccal canals were identified (Figure 4B). A CBCT scan performed before for a surgical procedure was accessed to further understand this unusual anatomy, and used to confirm the diagnosis of a maxillary first molar

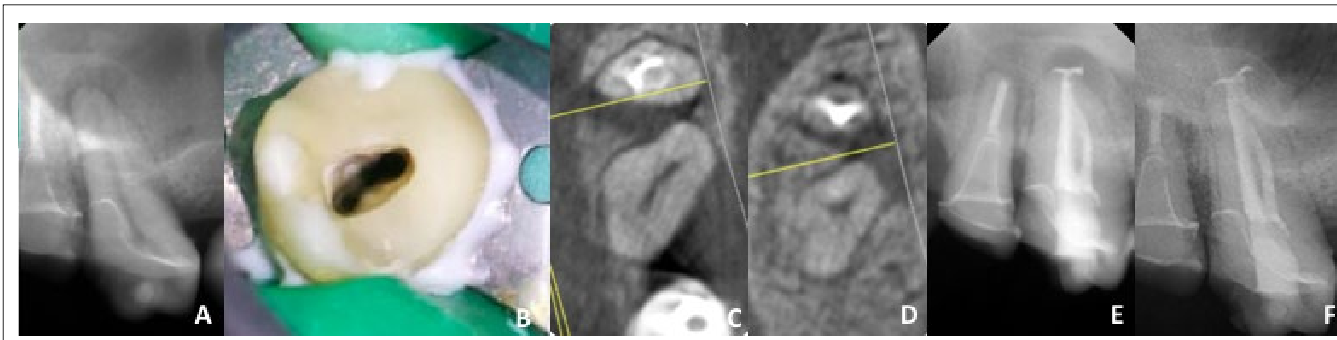

Figure 4.
A) Initial periapical radiograph of tooth 17, with periapical lesion and what appears to be a single root. **B)** Pulp chamber floor, with identifiable distopalatal and mesiobuccal canals. **C)** CBCT axial view, middle third of the root. A complete fusion of the roots of tooth 17, with two root canals can be observed. **D)** CBCT axial view, apical third. Both canals merge together. **E)** Final radiograph of the root canal treatment. **F**) Six months recall.

E2 C-shaped configuration (Figure 4C and 4D). Mechanical instrumentation was performed with Reciproc blue 25 and 40 files (Reciproc, VDW GmbH, Munich, Germany) and the canals filled (Figure 4E). At the 6 months recall inspection, the tooth showed no clinical findings, and an improvement of the periapical condition (Figure 4F).

Discussion

C-shaped root canal system morphologies have been presented as one of the most complex variations of the root canal system anatomy (11). This anatomic configuration is characterized by presenting a root canal system which may present several morphological features such as root canal merging, fusions and fins (6, 11). Although the higher prevalence of mandibular C-shaped molars has been associated with certain ethnic groups (12, 13), the same has not been proved for other groups of teeth, such as mandibular premolars and maxillary molars (14). The proportions of this morphology for both permanent maxillary molars are low, so any true variation between ethnic groups may go unnoticed. The prevalence on maxillary first molars may be as high as 1.1% (5), although several studies have reported not a single finding (15-17). As for the second molars, the percentages of cases may reach 3.8% (5) in a Portuguese sub-population, with other studies reporting even lower proportions 1.9% (16) and 0.9% (18) in Polish and Thai sub-populations, respectively. Just as in first molars, no findings have also been reported (17, 19).

As opposed to the mandibular C-shaped molar, in which the internal root canal system morphology is dependent of the fusion between two roots (mesial and distal) (20), leading to some predictability of the C-shaped configuration, the maxillary C-shaped configuration is dependent on the fusion of two or three roots, which leads to a superior variability of this inner anatomic configuration in these group of teeth (5). Moreover, and as has already been noted in a previous study (8), the fusion between the roots in a maxillary C-shaped molar may not be a true fusion. Instead, it may be described as non-division of roots because of inadequate development during the embryological phase of root formation due to what might have been an incorrect invagination of the epithelium of the Hertwig's horizontal root sheath. Since it can be described as inadequate root development, it may be difficult to classify different types of C-shaped configurations. However, with the information available from the published studies (6, 8), it is possible to understand that five types (and two sub-types) of configurations can be described depending on the roots that are fused (5).

The cases reported in this study represent three different anatomic configurations for the maxillary first and second molar. The first and third cases morphologies represent two possible variations of the buccal C-shaped canal (connecting both mesiobuccal and distobuccal root canals) depending to which side the convexity of the C is facing, while the second and fourth reported cases represent anatomies with fusions between the mesial and palatal root canals, which resemble the type C2 of Melton's classification for the mandibular molar (21). The root presents a semi-lunar cross-section in the middle and apical portion of the root due to the incomplete division of the three usual roots. The root canal system appears to be a complex system with a semi-lunar disto-palatal root canal that connects to an independent mesiobuccal root canal by an isthmus and then both canals converge together apically.

In the four cases presented, the use of a dental operating microscope, confirmation of the clinically observed C-shaped morphology through previously obtained CBCT images, and the use of specific ultrasonic tips allowed the clinicians to properly manage these uncommon configurations while eliminating the possibility of misguided and unnecessary elimination of dentin (22-26).

Mechanical instrumentation of C-shaped canals poses a challenge to the clinician.

The increased volume of the root canal space, the oval configuration and the existence of irregularities increase the occurrence of areas left untouched by endodontic files (27, 28), and the possibility of incomplete elimination of contaminated pulp tissue, dentine debris and adhered bacterial biofilm (29). Moreover, care must be taken not to overly enlarge the already thin dentinal walls (30). Both reciprocating and rotary files have been reported to perform equally in oval canals, with no difference in untouched canal areas and similar increase in overall preparation volume gain (31).
In these intricate variations of internal anatomy, the role of chemo-mechanical debridement becomes paramount (32). In the present study, 5.25% sodium hypochlorite (NaOCl) was used as an irrigant because of its strong disinfectant and antibacterial effects, as well as its ability to remove organic debris (33). In the final irrigation protocol, either manual dynamic agitation with a tapered gutta percha cone, or ultrassonic activation were applied, to further enhance the action of the employed irrigants (34). Such supplemental techniques of irrigation are essential to maximise the potential of the irrigants employed and play a decisive role in the outcome of treatment of C-shaped anatomies (29, 35).
Fused root morphology can result in root canal merging, and in some cases, multiple root canals can merge into a single portal of exit (36, 37). This anatomic particularity can contribute to a good quality apical seal, stated as a significant factor for the outcome of the endodontic treatment (38, 39), and hence minimize the effect of the complexity of a C-shaped configuration on the success of root canal therapy.
However, one of the cases required the application of an apical barrier of MTA since the gauged apical diameter would not allow an adequate apical seal with the thermoplastic technique alone. MTA is a biocompatible material that has been shown both *in vitro* an *in vivo* to have excellent adaptability to the canal walls (40).
Assessment of root canal treatment outcome should be made one year after the procedure, both clinically and radiographically (41). Even though CBCT is considered superior for diagnostic purposes, periapical radiographs also have good accuracy and are commonly employed for post-treatment evaluation in the absence of contradicting or non-specific signs and symptoms (42). Although in three of the presented cases follow-ups were made prior to the one year mark, there were already indications of resolution of periapical pathosis, and maintenance of periapical health in the case where no alteration was identified at the time of treatment, which may be considered as indicative of success of the endodontic treatment (43).
The actual impact of this uncommon root canal anatomy on the outcome of endodontic treatment needs further assessment.

Conclusions

The C-shaped anatomic configuration is an uncommon condition in both first and second maxillary molars. The available literature suggests the existence of five configuration types, depending on where the non-division of roots occurred in the tooth developmental phase. The use of the dental operating microscope and CBCT scan images leads to a better understanding of this rare anatomy, and ultrasonic tips assists in managing these root canal configurations. Optimization of irrigation protocols is essential to ensure a good outcome of endodontic therapy. As long as the biological principles prevail, the root canal treatment of these teeth appears to have a favorable outcome, as depicted in the four cases described.

Clinical Relevance

Knowledge of canal anatomy and its possible variations, including C-shaped anatomies in maxillary permanent molars, is paramount to ensure the success of endodontic treatment.

Conflict of Interest

Nothing to declare.

Acknowledgments

Nothing to declare.

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