IEJ Iranian Endodontic Journal

Endodontic Treatment of C-shaped Mandibular Premolars: A Case Report and Review of Literature

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ARTICLE INFO

Article Type: Case Report

Received: 25 Apr 2021
Revised: 26 Jul 2021
Accepted: 09 Aug 2021
Doi: *10.22037/iej.v16i4.34187*

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ABSTRACT

Our article aimed to present a curious case of a mandibular premolar with a C-shaped root canal and to review the available literature on this anatomical variation. Mandibular premolar teeth account for the greatest endodontic challenges in the course of treatment on account of the morphological variations in their root canal systems, including extra root(s)/canal(s) or a C-shaped configuration. A 20-year-old female patient was referred to the Department of Endodontics of Mashhad Faculty of Dentistry, suffering from abscess, and pain while chewing. On examination the culprit was found to be the left mandibular first premolar. Following special tests and periapical radiography, we found an amalgam restoration proximate to the non-vital pulp chamber, as well as an unusually complex root canal anatomy with periapical radiolucency. A non-surgical root canal treatment with the aid of a dental operating microscope was considered as the treatment plan. Clinicians should always anticipate the presence of a C-shaped configuration in mandibular premolars, and make use of all the available tools to locate and treat such cases. A substantial knowledge of root canal anatomy would be prudent to ensure a successful outcome ensuing surgical and non-surgical root canal treatments.

Keywords: Anatomic Variation; C-shaped Configuration; Endodontic Treatment; Mandibular Premolar

Introduction

An in-depth knowledge of the root canal morphology and tooth anatomy is a key requisite for successful endodontic treatment [1]. C-shaped root canal configuration is mostly found in mandibular second molars, followed by mandibular first premolars [2]. There are hypotheses that believe that the C-shaped root canal anatomy in mandibular premolars, like other teeth, is caused by a reduction in the speed of dentine formation on the lingual side [3]. This phenomenon has also been associated with failure of the Hertwig's epithelial root sheath to fuse on the lingual or buccal surface of the root [4]. Another factor deemed to contribute to a C-shaped root formation is the genetic change in the X chromosome [5].

According to Fan *et al.* [6], each cross-section of C-shaped canals in mandibular first premolars could be classified into the following categories and sub-categories:

- Category I [C1]: a continuous "C" shape with no separation or division;
- Category II [C2]: the canal resembling a semicolon in shape, as a result of an interruption in the "C" outline;
- Category III [C3]: two separate round, oval, or flat canals;
- Category IV [C4]: only one round, oval, or flat canal in the cross-section; C4a [round canal]: the long canal diameter being almost equal to the short diameter; C4b [oval canal]: the long canal diameter being at least 2 times shorter than the short diameter; C4c [flat canal]: the long canal diameter being at least twice as long as the short diameter;
- Category V [C5]: three or more discrete canals in the cross-section;
- Category VI [C6]: absence of any canal lumen or intact canal [usually observed near the apex only].

Cleaning and shaping during root canal therapy as well as surgical treatment of a C-shaped canal is an endodontic

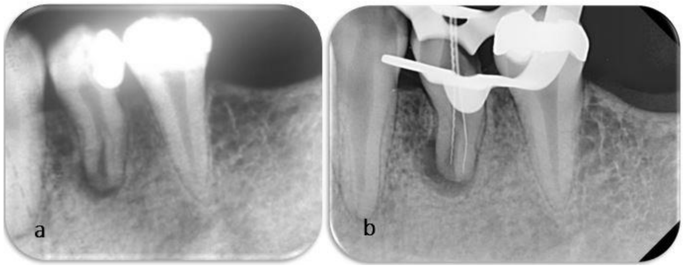

***Figure 1*:** Periapical radiographs of tooth #21; *A)* Diagnostic periapical radiograph shows an unusual complex root canal anatomy; *B)* Working length determination radiograph shows two files in two canals

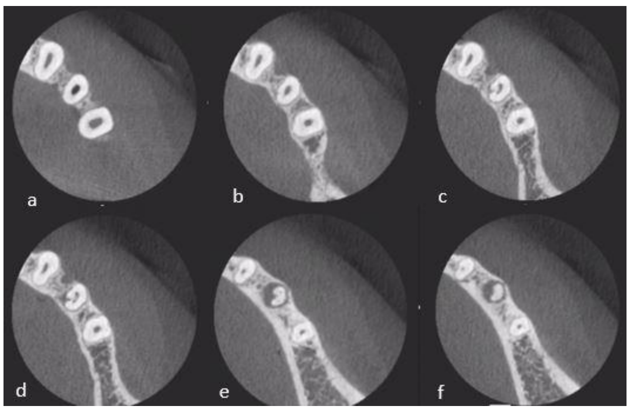

Figure 2: A CBCT scan of the C-shaped left mandibular first premolar axial view: *A and B)* Radicular coronal third; *C and D)* Radicular middle third; *E and F)* Radicular apical third

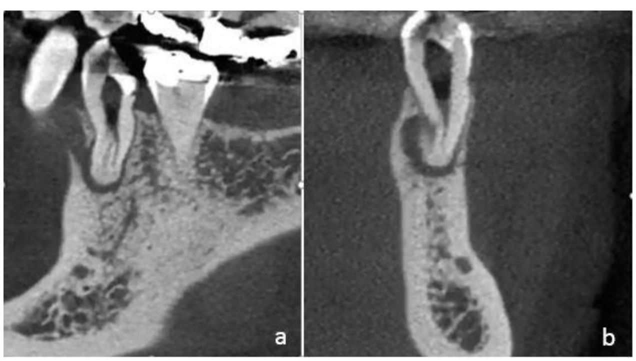

Figure 3: A) Sagittal view of CBCT shows the bifurcation of canals in middle third; *B)* Coronal plane of CBCT shows root depression located in the buccal surface

challenge due to the thinness of the root as well as the presence of concavities in that area [7]. Another potential mishap is improper root canal preparation, which could lead to a strip perforation. Comprehensive knowledge of root canal morphology using cone-beam computed tomography (CBCT) can lead to true diagnosis and management [8].

What follows is a description of the endodontic treatment of a rare C-shaped mandibular first premolar which was diagnosed using CBCT imaging.

Case Report

A 20-year-old female patient who presented with a non-contributory medical history was referred to the Department of Endodontics of Mashhad Faculty of Dentistry, Mashhad, Iran, suffering from abscess and pain while chewing; which was found to be related to the left mandibular first premolar.

Radiographic examination of the tooth showed an amalgam restoration proximate to the pulp chamber along with periapical radiolucency. An unusual complex root canal anatomy was observed (Figure 1A).

The tooth was slightly sensitive to percussion and was non-responsive to cold test using a -45 °C refrigerant spray (Frisco Spray, Arztbedarf, Frechen, Germany) and electrical pulp tester (EPT) using a digital EPT (Parkell, New York, USA), indicating pulp necrosis. Periapical diagnosis was consistent with acute apical periodontitis.

A non-surgical root canal treatment was considered as the treatment plan. An informed consent was obtained from the patient before starting endodontic treatment. At the first visit, inferior alveolar nerve block and long buccal nerve block was administered with 1.8 mL of 2% lidocaine and 1:100,000 epinephrine (Darupakhsh, Tehran, Iran). After rubber dam isolation and removal of amalgam restoration, an access cavity was made. A C-shaped root canal system under a dental operating microscope (Carl Zeiss Meditec Inc., Dublin, CA, USA) was identified. Two canals (buccal and lingual) were further identified within the C-shaped root canal configuration.

The working length of the buccal and lingual canals was established using an apex locator (Root ZX II mini, J Morita USA, Irvine, CA, USA) and a conventional radiographic method, as illustrated in Figure 1B. The canals' orifices were enlarged with ProTaper Gold (SX) (Dentsply Tulsa Dental, Tulsa, OK, USA), and the two canals were instrumented with stainless steel hand K-files up to size 15 (Flexofiles; Dentsply Maillefer, Ballaigues, Switzerland) and HERO shaper rotary system (Micro Mega, Besancon, France) up to size 25/0.04 under copious irrigation with 5.25% sodium hypochlorite (Chlora, Cerkamed, Stalowa, Poland). Then, the root canal system was dried using paper point (AriaDent, Tehran, Iran) and dressed with calcium hydroxide paste and subsequently, sealed coronally with Cavit (ESPE, Seefeld, Germany).

CBCT image was taken using Planmeca ProMax 3D (Planmeca, Helsinki, Finland), which confirmed the C-shaped configuration of the root canal as well as the presence of the two canals (Figures 2 and 3).

At the second visit, the patient was asymptomatic. We administered inferior alveolar nerve block with 2 mL of 2%

Figure 4: Final radiograph; *A)* C-shaped canal was obturated; *B)* Periapical radiograph of tooth #21 in the second appointment (after six months); *C)* Follow up radiograph after 21 months shows that healing is almost complete

lidocaine. After rubber dam isolation and removal of the cotton pellet and the temporary restoration, we removed calcium hydroxide from the root canals by XP-Endo Finisher (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) and copious irrigation with 5.25% sodium hypochlorite solution. The isthmus areas were also cleaned and shaped with #6, 8, and 10 K-files, and were irrigated using 5.25% sodium hypochlorite. Subsequent to preparation of the canals, 5.25% sodium hypochlorite was agitated for 60 sec using the EndoActivator (Dentsply Tulsa Dental, Tulsa, OK, USA). We used 17% EDTA for one minu to remove the smear layer. The canals were dried using paper points. They were filled with gutta-percha and AH-26 sealer (Dentsply Maillefer, Ballaigues, Switzerland) using the warm vertical compaction technique. Finally a cotton pellet was placed in the pulp chamber, and the tooth was temporized with IRM (intermediate restorative material based on zinc oxide/eugenol) (Dentsply Caulk, Milford, DE, USA) as demonstrated in Figure 4A. Ultimately, the patient was referred to the Department of Restorative Dentistry for permanent restoration. At the six-month follow-up visit, noticeable healing of the lesion was observed in the periapical radiogragh (Figure 4B). The patient returned to the endodontic clinic 21 months later. Radiographic and clinical examination revealed an intact, asymptomatic, healed, and functioning tooth (Figure 4C).

Review of Literature

Search strategy

A literature search for relevant articles regarding endodontic treatment of C-shaped mandibular premolars was performed using Cochrane Database of Systematic Reviews, EMBASE, Scopus, and MEDLINE.

The following key words were used in the search: "Mandibular premolar" OR ''Root canal configuration" OR "Root canal morphology" OR "Root canal anatomy" OR "Anatomic variation" AND "C*shape". After removal of duplicate articles, the titles and abstracts of the remaining articles were individually screened for applicability by two researchers (M. K. and S. N.). We manually checked the list of references in each article to retrieve further eligible papers. English studies that reported C-shaped root canal in mandibular premolars, whose full texts were available were included in the study.

Prevalence

Numerous factors may affect the prevalence of abnormal root canal morphology reported in published studies, including gender, ethnic background, data collection method, sample size, and the mode of examining the root canal system [9, 10]. Table 1 demonstrates the findings from various anatomical studies based on geographical population. The table details the prevalence of this condition in different African [1, 11] Caucasian [1, 7, 12-19], Indian [20-24], Chinese/Mongoloid [25-34], and Middle East populations [35-43]. Two studies reported a prevalence of 1.1% and 1.14% with respect to C-shaped root canal configuration in mandibular first premolars in a Chinese population [44]. A prevalence study among the northwestern Iranian population revealed that 98% of mandibular first premolars had one root, 2% had two roots, and 2.4% of the cases possessed a C-shaped root canal system [39].

Fan *et al.* [27] reported the highest prevalence [24%] of C-shaped root canal configuration in mandibular first premolars in a Chinese population. Various methods have been used to identify a C-shaped canal. CBCT was used in our study for definitive diagnosis of the C-shaped canal as previous investigations [25, 28, 31, 32, 43, 45].

Table 1. Prevalence of C-shaped root canal configuration in mandibular premolars

Author(s)	Tooth type	Sample size	Total %	Method of Sudy
		Population: African		
Zillich and Dawson [1]	First premolar	400	0%	*In vivo*: radiographic examination
Mbaye *et al.* [11]	First premolar	412	0%	*In vivo*: radiographic examination
Mbaye *et al.* [11]	Second premolar	408	0%	*In vivo*: radiographic examination
		Population: Caucasian		
Barrett [12]	First premolar	32	0%	*In vitro*: sectioning
Mueller *et al.* [15]	First premolar	156	0%	*In vitro*: radiographs
Green [14]	First premolar	50	0%	*In vitro*: grinding and examination under magnification
Zillich and Dawson [1]	First premolar	1287	0%	*In vitro*: Extraction and radiograph
Vertucci [19]	First premolar	400	0%	*In vitro*: clearing
Vertucci [19]	Second premolar	400	0%	*In vitro*: clearing
Trope *et al.* [18]	First premolar	400	0%	*In vivo*: radiographic examination
Geider *et al.* [13]	First premolar	341	14%	*In vitro*: radiograph and sectioning
Baisden *et al.* [7]	First premolar	106	0%	*In vitro*: sectioning
Sabala *et al.* [17]	First premolar	1002	0%	*In vivo*: radiographic examination
Różyło *et al.* [16]	First premolar	83	1.4%	*In vitro*: Extraction and RCT
Różyło *et al.* [16]	Second premolar	56	0%	*In vitro*: Extraction and RCT
		Population: Indian		
Sikri and Sikri [23]	First premolar	112	10.7%	*In vitro*: SCT
Velmurugan and Sandhya [24]	First premolar	100	1%	*In vitro*: clearing
Sandhya *et al.* [22]	First premolar	100	2%	*In vitro*: Spiral-computed tomography (SCT)
Parekh *et al.* [21]	First premolar	40	0%	*In vitro*: clearing
Parekh *et al.* [21]	Second premolar	40	0%	*In vitro*: clearing
Jain and Bahuguna [20]	First premolar	138	0%	*In vitro*: clearing
		Population: Mongoloid		
Miyoshi *et al.* [30]	0%	516	First premolar	*In vitro*: radiographs
Walker [33]	0%	100	First premolar	*In vitro*: radiographs
Yoshioka *et al.* [34]	0%	139	First premolar	*In vitro*: staining
Lu *et al.* [29]	0%	82	First premolar	*In vitro*: radiograph and sectioning
Fan *et al.* [48]	24%	358	First premolar	*In vitro*: Micro-CT
Qian *et al.* [31]	4.1%	97	First premolar	*In vivo*: CBCT
Tian *et al.* [32]	1.1%	178	First premolar	*In vivo*: CBCT
Tian *et al.* [32]	0.6%	178	Second premolar	*In vivo*: CBCT
Liu *et al.* [28]	0%	115	First premolar	*In vivo*: Micro-CT
Tian *et al.* [32]	1.1%	440	First premolar	*In vivo*: CBCT
Dou L *et al.* [26]	12/36%	178	First premolar	*In vivo*: Micro-CT
Chen *et al.* [25]	2.24%	580	Second premolar	*In vivo*: CBCT
		Population: Middle East		
Çalişkan *et al.* [36]	0%	100	First premolar	*In vitro*: clearing
Zaatar *et al.* [42]	0%	20	First premolar	*In vivo*: radiograph of RCT teeth
Sert and Bayirli [41]	0%	200	First premolar	*In vitro*: clearing
Hasheminia and Hashemi [37]	0%	80	Second premolar	*In vitro*: clearing and sectioning
Rahimi *et al.* [39]	2.4%	163	First premolar	*In vitro*: clearing
Rahimi *et al.* [40]	0%	137	Second premolar	*In vitro*: clearing
Awawdeh and Al-Qudah [33]	0%	500	First premolar	*In vitro*: clearing
Awawdeh and Al-Qudah [35]	0%	400	Second premolar	*In vitro*: clearing
Khedmat *et al.* [38]	1.4%	217	First premolar	*In vitro*: sectioning
Zare Jahromi *et al.* [43]	0.44	228	First premolar	*In vivo*: CBCT
Zare Jahromi *et al.* [43]	0.44	228	Second premolar	*In vivo*: CBCT

Anatomical feature

Pulp chambers of mandibular premolars with a C-shaped canal often exhibit greater apico-occlusal width with a low bifurcation [46]. The result will be a deep pulp chamber floor with an uncommon anatomical configuration [47].

Shallow or deep radicular grooves, situated on the external mesio-lingual surface of the root, are found in all C-shaped premolars [27, 29, 48]. Such grooves often emerge 3 mm below the cementoenamel junction (CEJ) and might extend to the apex [27]. Buccal radicular grooves may be seen in mandibular premolars with a reversed C-shaped canal system [25, 27]. At some areas on the root, the mean depth of these grooves can be around 1.5 mm [27]. A higher ratio of groove-to-thickness in mandibular premolars suggests a greater likelihood for the existence of a C-shaped canal system [25, 26, 49].

The C-shaped root canal configuration in mandibular premolars is mainly observed at the middle and apical third of the root [25, 27, 29, 50]. Thus, a single canal is usually seen at the coronal third of the root during access preparation in mandibular first and second premolars [25]. Fan *et al.* [27] and Gu *et al.* [50] have proposed extension of the access in bucco-lingual directions in order to locate the second canal as well as bifurcations at the middle and apical third of mandibular premolars.

Diagnosis

Radiographic diagnosis

A preoperative radiograph tends to offer many useful clues towards the identification of any variation in root canal morphology. Expert opinion is divided concerning the value of preoperative radiographs in terms of diagnosing a C-shaped root canal configuration. With regard to mandibular premolars that exhibit canal bifurcation and canal discontinuity on the bucco-lingual view, it is important to consider the possible existence of a reversed C-shaped canal [25]. An additional radiographic view from a 15-20° mesial or distal projection can deliver valuable information about root canal morphology [51-53].

Radiographic images during canal negotiation may expose two features of canal configuration: I) the instruments' tendency to converge at the apex; II) probable exit of the instruments at the furcation [54]. The latter may sometimes resemble a perforation at the furcation region [54-57]. This finding, along with the scarcely distinguishable floor of the pulp chamber, can contribute to radiographic identification of a C-shaped root canal configuration [58]. In addition, employing a third-generation apex locator with the capability to read the lengths of canals in the presence of electrolytes should help establish a more accurate diagnosis [56].

Radiographic interpretation is generally more efficient when it is based on film combinations ["preoperative plus working length radiographs" or "preoperative plus final radiographs" or "all three radiographs"] as compared with the application of single radiographs. Working length radiographs are believed to be more beneficial than preoperative or final images in diagnosis of a C-shaped root canal system, with preoperative radiographs being the least effective [58].

Conventional dental imaging shortcomings are resolved by means of three-dimensional imaging, such as CBCT and MRI. CBCT is known as a non-invasive three-dimensional imaging technique which according to literature, sufficiently precise for the purpose of performing morphological analysis [59].

Clinical diagnosis

The crown morphology of mandibular premolars with a C-shaped canal system does not reveal any distinctive features to aid in the endodontic diagnosis. A root canal with a C-shaped anatomy may include a longitudinal groove on its lingual or buccal surface [6]. As a result of these narrow grooves, the tooth may become predisposed to localized periodontal diseases; considered the first diagnostic indication [46].

We can only clinically identify a C-shaped root canal configuration after access to the pulp chamber [56, 58]. In C-shaped canal systems, the pulpal floor can vary in shape from peninsula like, with an uninterrupted C-shaped orifice, to non-C-shaped floors, according to the classification provided by Min *et al.* [60]. Once we ascertain C-shaped canal orifice , for example, under the operating microscope, it should not be assumed that such a shape extends throughout its length [6].

The pulp chamber with a C-shaped canal system might be slightly larger in the occlusal-apical dimension, and exhibit a low bifurcation anatomically [61].

A true C-shaped root canal configuration, in which a single canal extends from the orifice to the apex, allows the filing instrument to pass from the mesial to the distal aspect without obstruction [46]. Such passage is hindered by disconnected dentine bridges when dealing with other configurations [56].

Root canal system preparation

As far as mandibular premolars with a C-shaped root canal configuration are concerned, a set of complicating factors make the treatment process particularly difficult, especially in comparison with mandibular second molars. The C-shaped morphology that is present in some mandibular second molars is often discovered coronally and is up to 3 mm apical to the CEJ. Therefore, this C-shaped configuration is more readily identified through observation of the pulp chamber floor as compared to premolars. The premolars can present a coronal single oval canal, and subsequently, further down the root, it could change to C-shaped anatomy at 3 mm- and/or 6 mm-level cross-sections from the apical region. This complicating feature makes the identification of C-shaped anatomy a great challenge for treating clinicians [27, 29].

The anatomical width and diameter of mandibular premolars are considerably smaller compared to mandibular second molars, which further limits coronal access to the apical section of the root canal system. Naturally, detection of such C-shaped canals from the coronal direction would be difficult. This highlights the significance of performing coronal enlargement under enhanced illumination and magnification with ultrasonic tips, as well as employing a dental operating microscope assisted by CBCT, not forgetting careful planning [62, 63].

Also, the application of fiber-optic trans-illumination can be of great help in identification of various canal anatomies. Placement of the fiber-optic tip under the rubber dam on the buccal surface will illuminate the pulp chamber. This way, the canal system will appear in the form of a dark line or area within the illuminated field [54].

The root canal treatment of a C-shaped mandibular premolar is a clinical challenge due to certain characteristics of such configuration: concavities, small root thicknesses, and narrow-flat canals. The required mechanical canal instrumentation may inadvertently remove excessive dentine, and consequently cause ledge, strip perforation, canal transportation, and apical perforation. Lingual walls at the coronal, middle and apical thirds of the root are generally thinner than buccal walls, and this is particularly true in mesial locations [62]. To avoid inadvertent perforation, Abou-Rass *et al.* [64] has recommended the application of anti-curvature filing technique. However, the isthmus areas are advised not to be prepared with any file larger than size 25; otherwise, it is possible to inflict strip perforation. Sufficient application of small files together with 5.25% sodium hypochlorite is critical for thorough debridement of isthmus areas in narrow canals [54].

According to Jafarzadeh *et al.* [65] , great care should be taken to avoid instrumentation beyond the apical foramen, as it may induce postoperative pain and sensitivity. Likewise, obturation beyond the radiographic apex can decrease the success rate of root canal treatment.

The apex locator proved to be more accurate in terms of determining the working length within a C-shaped canal configuration, compared to conventional radiography methods. Though nickel-titanium rotary instruments are believed to be safe for application in C-shaped canals, further enlargement of the apical dimension to any extent greater than size 30 (0.06 taper) is unadvisable [66]. Subsequent to instrumentation with NiTi rotary instruments, K-files or H-files should be passively introduced into the canal, and the filling procedure should be specifically directed toward the isthmus areas in order to achieve better debridement in a clinical practice [67].

The newly designed self-adjusting file (SAF) system (ReDent, Raanana, Israel) has been claimed to be more efficient in comparison with the ProTaper system (Dentsply Tulsa Dental, Tulsa, OK, USA) for the purpose of shaping C-shaped canals [68]. The SAF system, which contains a hollow core with an interlocking lattice design, shapes the root canal while adapting to the size of the canal walls so as to remove a uniform layer of dentin. In addition, this system offers effective irrigation [69]. However, we did not use this in our case study. Dilek Helvacioglu--Yigit [69] reported that the supplementary application of SAF system following the use of rotary instruments in the treatment of C-shaped root canals may be a promising method for endodontic management of this type of canal morphology.

The XP-Endo finisher file is straight at room temperature, because the crystalline structure of the nickel-titanium alloy of this file is in M-phase. When inserted in a canal and reaching body temperature, this file will change shape owing to its molecular memory to turn into the A-phase. When in rotation mode, it is claimed that the shape developed during the A-phase allows this file to access and clean areas that other conventional instruments are not able to reach. This file, according to the manufacturer, follows the canal walls with an enhanced reach of 6.0 mm in diameter compared with a standard instrument of the same size, enabling the instrument to contact more surfaces on the walls of the canals. All these features render this file efficient for the treatment of C-shaped canals [62].

The employment of adjuncts designed to accompany cleaning and shaping in the form of, for example, passive ultrasonic irrigation, apical negative pressure irrigation, or other dynamic modes of irrigation could be of great use in terms of achieving enhanced disinfection results, cleansing the uninstrumented apical bi- and tri-furcations, as well as managing lateral ramifications that are not at all easy to instrument [70]. The application of a smaller-diameter irrigation needle could lead to improved irrigation flow into the irregularities of the root canal system [71].

Obturation

The intended obturation procedure should, in a predictable manner, drive gutta-percha and sealer into the irregularities of the root canal system [3]. The application of the lateral condensation method alone makes sealing of the isthmus areas difficult. Since these isthmus areas cannot be sufficiently flared during the preparation phase, deep placement of the spreader may be impossible, which means the application of thermoplasticized gutta-percha is probably more suitable [54, 72].

With regard to root canal obturation, Kim *et al.* [73] evaluated warm gutta-percha filling techniques in comparison with conventional cold lateral condensation employing a number of simulated C-shaped root canals which were embedded in resin blocks. Their study concluded that the application of warm gutta-percha condensation techniques is expected to lead to favorable results in terms of canal filling in C-shaped root configurations. Nevertheless, a meta-analysis incorporating ten clinical studies revealed no significant difference in terms of the long-term outcome between warm gutta-percha techniques and cold lateral condensation [74].

Endodontic surgery

Surgical endodontic treatment of anomalous mandibular premolars can be conducted in conjunction with an orthograde root canal procedure, particularly in the case of complex C-shaped canals or apical tri-furcations. It is critical to carefully examine the resected root end for the presence of circumferential openings with a dental operating microscope. This practice makes it possible to identify any apical third variations, and hence their subsequent retrograde management [63]. Lu *et al.* [29] has reported a higher incidence of apical ramifications in the 3-6 mm apical region of C-shaped Chinese/ Mongoloid mandibular premolars. In such cases, the suggested procedure involves root-end resection at lengths greater than the frequently selected landmark of 3-mm, promising a successful clinical outcome [63].

If an apical etiology and/or apical surgery causes failure, other viable options can be pursued, including: extraction, extraoral retrofilling, and replantation. The generally conical nature of C-shaped roots makes them easy to extract, without causing fracture [54].

Restoration

A study by Chen *et al.* [25] concluded that the deepest radicular grooves probably exist in the axial half of the root in most teeth. In mandibular premolars with a C-shaped configuration, however, it is mostly present in the apical half of the root. If a mandibular premolar tooth with a C-shaped canal system requires a post for permanent restoration following root canal treatment, the preparation of the post space ought to be performed carefully due to the thinner dentinal wall and smaller tooth size. It is advisable that the post be placed within the coronal third section of the root in order to avoid perforation.

Discussion

The case report of the current study represents the successful endodontic management of a C-shaped mandibular first premolar with two short root canals. The C-shaped canal was observed using two-dimensional radiographic imaging, and was subsequently verified through visual inspection under the microscope. Two canals (buccal and lingual) were also identified within the C-shaped canal. Endodontic treatment of mandibular premolars requires a comprehensive knowledge of the morphological/anatomical variations, specially of the uncommon anatomical features [9, 75]. A C-shaped root canal configuration, though an unusual morphology, can lead to difficulties in root canal treatment. The presence of extra root(s) in mandibular first premolar is an additional challenge [76-78].

Due to the diversity of the recognized variations in C-shaped canal systems, CBCT imaging was used to analyze the uncommon C-shaped root canal configuration, and to ensure proper instrumentation to assist cleaning and avoid root fracture. A CBCT scan is a practical tool for better understanding of the root canal morphology [79]. However, it comes with certain disadvantages, including: limited capability to visualize internal soft tissues; susceptibility to movement artifacts; and low contrast resolution. Also, the CBCT method cannot be used to estimate bone density [80]; therefore, these scans should only be prescribed when an aberrant anatomy has been identified using two-dimensional radiographic imaging or clinical examination of teeth. CBCT imaging should not be prescribed for the purpose of routine endodontic treatment of mandibular premolars [80].

When sagittal, coronal, and axial CBCT images are combined, they provide the clinician with a greater in-depth understanding of the root canal morphology. Axial images tend to be more accurate, because they can show C-shaped configurations at different levels of the root, facilitating the assessment of the thin areas of dentin in the danger zone. According to the classification proposed by Fan *et al.* [6], as mentioned earlier in this article, the analysis of the axial slices showed C4, C1, and C3 configurations in the coronal, middle and apical thirds of the root, respectively.

The residual dentin thickness has been recommended to be at least one-third of the root, since instrumentation exceeding this threshold may escalate the risk of root fracture. In a report by Jafarzadeh and Wu, they proposed that instrumentation with files larger than size 25 can lead to strip perforation [61]. The presence of isthmus areas, fins, and irregularities may cause further complications during the treatment of C-shaped premolars. Yin *et al.* [67] reported that, regardless of the instrumentation technique used, a large proportion of the canal surface can remain untouched in C-shaped root canals. The sufficient use of small files along with 5.25% sodium hypochlorite is a key factor in successful debridement of narrow areas of the canal isthmus. Furthermore, Jafarzadeh and Wu [61] recommended that deeper penetration with the use of small instruments (sonics or ultrasonics) could be more effective for thorough debridement and cleansing of the isthmus area. However, extreme care should be exercised during ultrasonication to avoid perforation of the narrow isthmus areas in C-shaped roots.

In this case report, isthmus areas were cleansed and shaped using copious irrigation with NaOCl and application of small hand files. The EndoActivator (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) was employed to agitate sodium hypochlorite and to maximize root canal disinfection. Final irrigation with 17% EDTA helped to remove the smear layer. Dental operating microscope as well as radiographic examination along with CBCT imaging were used to facilitate accurate diagnosis of the root canal configuration, which consequently led to the successful endodontic management of this case.

Conclusion

Our case report highlights that anatomical variations can complicate endodontic treatments. With correct diagnosis and treatment planning, this complex case was successfully treated. Our literature review suggests that the future of endodontics will rely on the application of dental operating microscope, advanced irrigation systems for near perfect debridement of the root canal system, and more innovative techniques such as CBCT and micro−CT for complicated root canal morphologies.

Conflict of Interest: 'None declared'.

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Please cite this paper as: Khorasani M, Nabavi S , Hamedi A, Jafarzadeh H. Endodontic Treatment of C-shaped Mandibular Premolars: A Case Report and Review of Literature. Iran Endod J. 2021;16(4): 244-53. *Doi: 10.22037/iej.v16i4.34187.*