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Incidence of the middle mesial canals in mandibular permanent molars in a Romanian population by cone-beam computed tomography

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Abstract

Introduction: Untreated middle mesial canals (MMCs) of mandibular permanent molars can result in endodontic treatment failure. *Aim*: The aim of this retrospective study was to investigate the incidence of MMC of mandibular molars in a Romanian population. *Patients, Materials and Methods*: In total, there were evaluated 144 mandibular first permanent molars and 140 mandibular second permanent molars by using cone-beam computed tomography (CBCT) scans. *Results*: The MMC was identified in 5.67% of mandibular first permanent molars, respectively in 4.28% of mandibular second permanent molars. The male/female ratio of MMC presence was 1:3 of mandibular first molars and inverted for mandibular second molars (5:1). The presence of MMC in mandibular first molars was associated in all cases of our study with a second distal canal, unlike the mandibular second molars where no second distal canal was associated with a MMC. *Conclusions*: In Romanian population, the MMC of mandibular first molars, when present, is commonly associated with a second distal canal, unlike the mandibular second molars where the occurrence of a MMC was associated with only one distal canal. When performing the preoperative evaluation, it has also to be considered the patient gender, since the male/female ratio of MMC was 1:3 in mandibular first molars and 5:1 in mandibular second molars.

Keywords: CBCT, mandibular molars, middle mesial canal, morphological variants.

Introduction

The successful outcome of the endodontic therapy is closely correlated with the ability of proper accessing, enlarging and filling of the root canal system. However, the efficiency of any root canal treatment is depending in the end on the unforeseeable internal morphology of the teeth, and the mandibular first and second permanent molars are not an exception from the rule.

The mandibular first permanent molar is normally a two-rooted tooth, with a mesial and distal root broader buccolingually than mesiodistally, which are separated at furcation level [1].

The canal system of a typical two-rooted mandibular first permanent molar presents two mesial canals 95.8% and one distal canal 68.3% of the time. The incidence of a single mesial canal is of 4.2% and of two distal canals of 31.7% [1].

According to Zhang *et al.* [2], the two-rooted mandibular first permanent molars reveal four morphological variants of the root canal system, as follows: only one canal in each root, one canal in the mesial root and two canals in the distal one, two canals in the mesial root and one canal in the distal one, and two canals in each root.

The mandibular second permanent molar is typically (76.2%) a two-rooted tooth with a mesial and distal root, broader buccolingually than mesiodistally, similar to the mandibular first permanent molar. However, unlike the first molar the roots are closer together and frequently may present in common a longer root trunk [1].

Normally, the canal system of two-rooted mandibular second permanent molars displays two canals in the mesial root and one canal in the distal one. However, unlike the mandibular first lower molar, the incidence of only one canal in mesial root of the second molar is higher (14%) [1].

Numerous clinical and radiographic studies report the unusual internal morphology of mandibular first molar that may have more than three root canals. Pomeranz *et al.* [3] succeeded to identify a middle mesial canal (MMC) in seven out of 61 mandibular permanent first molars and in five out of 39 mandibular permanent second molars.

Fabra-Campos [4] found that 20 (2.6%) out of 760 mandibular molars had a MMC. In another study of 145 endodontically treated mandibular first molars, Fabra-Campos [5] reported only four molars with three canals in mesial root. Unlike the mesial root, the distal one presented a higher incidence of canal aberrations [5]. Moreover, a number of 69 distal roots out of 145 mandibular first molars had two canals [5]. A review study of de Pablo *et al.* [6], including overall 4535 mesial roots of mandibular molars, reported two canals in 94.4% of cases and three canals in 2.3% of cases.

The conventional intra-oral periapical radiograph has a limited diagnostic performance because is the result of compressing three-dimensional (3-D) anatomy into a two-dimensional image. The root structure is visualized only in the mesio-distal plane, so that an accessory canal, such as the MMC of lower molars, may not be fully valued [7].

Cone-beam computed tomography (CBCT) is a more objective and accurate investigation technique than periapical radiography because it eliminates the superimposition of mineralized anatomical structures, by providing undistorted 3-D imagistic information [8].

CBCT is an effective and safe way to overcome the shortcomings of periapical radiographs. Using axial slices, CBCT may visualize unidentified root canals that escaped to conventional examination by periapical radiographs, even if taken with the paralleling technique at different angles of exposure [8].

Aim

The purpose of this study was to investigate the incidence of the MMC in mandibular permanent molars in a Romanian population using CBCT.

Patients, Materials and Methods

This retrospective study was performed over a period of three years and six months in the private dental offices of the participating dentists. The study was conducted in full accordance with the *World Medical Association* (WMA) Declaration of Helsinki. Written consent of the patients was obtained according to the above-mentioned principles.

There were collected CBCT images as part of the routine diagnosis and treatment planning. Therefore, in order to achieve a preoperative evaluation mainly for dental implants, impacted teeth, facial trauma, and tumors, there were enrolled 284 consecutive male and female patients. Additionally, in few cases, CBCT was used for endodontic assessment due to insufficient information provided by conventional intraoral radiographs.

In total, a number of 144 first mandibular permanent molars (89 females and 55 males) and 140 second mandibular permanent molars (77 females and 63 males) were analyzed by CBCT for the presence of an additional mesial canal.

Results

The CBCT examination showed an additional mesial canal (middle mesial) in eight mandibular first molars out of 144 (5.67%), respectively in six mandibular second molars out of 140 (4.28%) (Table 1). Excluding the wisdom teeth, a total of 4.92% out of 284 mandibular molars presented a MMC (Figure 1) on a CBCT image, which was clinically confirmed by an operative microscope (Figure 2).

Table 1 – *Frequency distribution (%) of MMCs in mandibular molars*

Tooth	No. of teeth	MMCs	Frequency
First molar	144	8	5.67%
Second molar	140	6	4.28%
Total	284	14	4.92%

MMCs: Middle mesial canals.

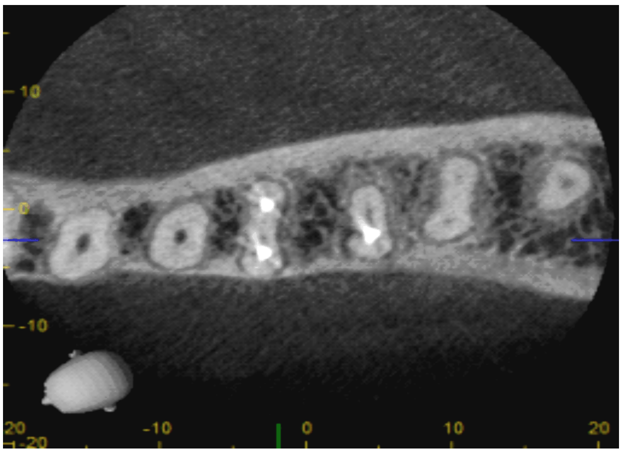

Figure 1 – *Preoperative transverse CBCT image showing three mesial root canals in tooth 36. The mesiobuccal and mesiolingual canals were previously instrumented and obturated. The middle mesial root canal is still untreated. A second untreated distal canal is also displayed. CBCT: Cone-beam computed tomography.*

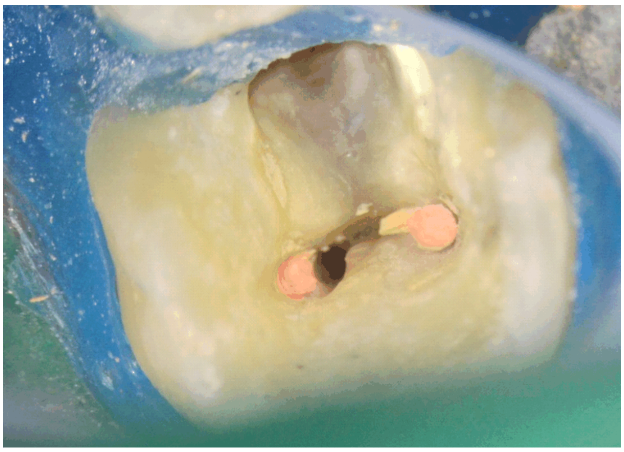

Figure 2 – *Pulp chamber floor of tooth 36 showing the gutta-percha filling of mesiobuccal and mesiolingual canals. The orifice of presently instrumented middle mesial canal is located close to the mesiobuccal canal.*

Depending on gender, the incidence of MMC in mandibular first molar was higher in females than in males (3:1 ratio). The female/male ratio of a MMC was inverted in the mandibular second molar, *i.e.*, 1:5 (Table 2).

In case of insufficient information provided by periapical radiographs for endodontic assessment (Figure 3), the use of CBCT enabled proper diagnosis and subsequent adequate treatment (Figure 4). It was also observed that the presence of MMC in mandibular first molars was associated in all cases of our study with a second distal canal (Figures 5 and 6).

In mandibular second molars, in total there were four canals (three mesial and one distal) when a MMC occurs (Table 3). Unlike the mandibular first molars, in mandibular second molars no second distal canal was associated with a MMC.

Table 2 – ***Gender-dependant distribution of MMCs in mandibular molars***

Gender	No. of subjects		No. of MMCs	
			First molar	***Second molar***
Males	55	63	2	5
Females	89	77	6	1
Male/female ratio			1:3	5:1

MMCs: Middle mesial canals.

Table 3 – ***Distribution of MMCs in mandibular molars based on molar type and presence of a second distal canal***

Tooth	No. of examined teeth	No. of teeth with MMC	No. of teeth with second distal canal
First molar	144	8	8
Second molar	140	6	0
Total	284	14	8

MMCs: Middle mesial canals.

Figure 3 – ***Preoperative periapical radiograph of tooth 36.***

Figure 4 – ***Postoperative radiograph of tooth 36 showing an independent middle mesial canal in mesial root and two canals in distal root.***

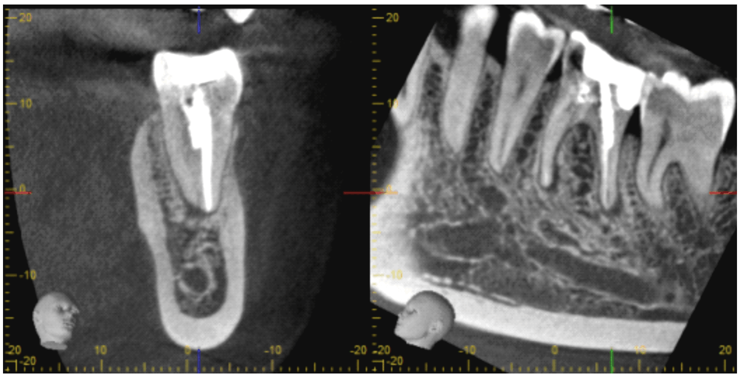

Figure 5 – ***Preoperative transverse, respectively longitudinal CBCT image showing the distal root of tooth 36 with previous filling of distobuccal canal. A metallic screw post is cemented in distolingual uninstrumented root canal. CBCT: Cone-beam computed tomography.***

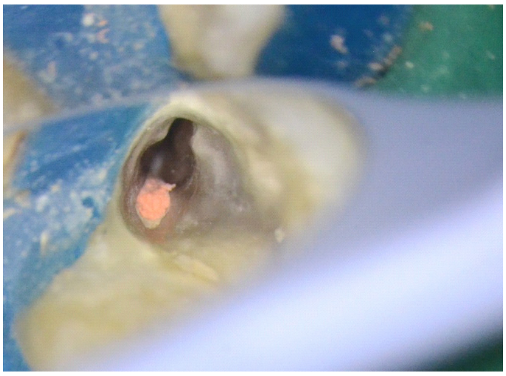

Figure 6 – ***Pulp chamber floor of tooth 36 showing the gutta-percha filling of disto-buccal canal and the orifice of presently instrumented distolingual canal.***

Discussions

The anatomy of the root canal system in mandibular first molars is controversially discussed in literature since the complexity of root canal configurations in individual cases does not match with already described classification systems. Although the variation of canal configurations occurs in both roots, it prevails in the mesial root. However, in mandibular molars, unlike the three-rooted form of first molars or the "C-shape" form of second molars, it seems that the configuration of the root canal system has no direct relationship with ethnicity [6].

The MMC is one of anatomical variations displayed by internal complexity of the endodontic system in mandibular permanent molars that are thought to be characterized by genetics and race [6, 9, 10].

The conventional methods used in current endodontic practice to identify root canals are clinical inspection with mirror and endodontic probe, and periapical radiographs. According to Corcoran *et al.* [11], the successful examination of the pulp chamber floor depends on operator knowledge, clinical experience and skill in detecting additional canals.

The use of magnified illumination provided by operating microscope is also increasing the possibility of locating the extra canals that cannot be identified by traditional visual inspection with the naked eye. However, it seems that the efficacy of the magnifying instruments is directly influenced by the learning curve of clinical training. The desired aim of correctly detecting and negotiating additional canals, such as the MMC of lower first molars can only be achieved through the experience gained by manipulating the microscope on patients [11].

The MMC is located in the groove that links the mesiobuccal and the mesiolingual canals of lower molars. It is of high practical importance to identify the MMC since this accessory root canal represents a real clinical challenge in the endodontic treatment of the mandibular first molar [12].

At visual inspection, the presence of mesial groove in the pulpal floor and the clear color difference between the dentin bordering the canal orifices and the dentin of pulp chamber floor are extremely useful clinical points of reference [13].

The literature survey points out those deviations from anatomical norm of the root canal system are not uncommon. The detection and treatment of additional root canals, such as the MMC of lower molars are definitely challenging, but the inability to adequately solve these issues results in failures [14].

Pomeranz *et al.* [3] divided the MMCs in three classes: independent (separate apical foramen), confluent apically with mesiobuccal or mesiolingual, and fin (free transverse communication with mesiobuccal or mesiolingual).

Nosrat *et al.* [9] encountered among 15 MMCs the following incidence in decreasing order: 46.7% confluent anatomy, 33.3% fin anatomy, and 20% independent anatomy. These results are in contrast with Pomeranz *et al.* [3], who found 67% fin anatomy or with Karapinar-Kazandag *et al.* [15], who described only confluent anatomy.

Moreover, Karapinar-Kazandag *et al.* [15] suggested that the MMC has to be considered an isthmus linking the main mesial canals mesiobuccal and mesiolingual, and not as an actual canal. Later on, in a study on 44 lower first molars de Toubes *et al.* [12] found under operating microscope that this accessory canal is situated in the mesial groove of the pulpal floor with the highest incidence closer to the mesiobuccal canal (46%), at the center of the groove (23%) or in the proximity of the mesiolingual canal (31%).

It was also observed under the operating microscope and confirmed by periapical radiographs in oblique projection that the MMC had an independent path to the apical foramen only in 8% of cases, whereas in the other cases it was connected either to the mesiobuccal (54%) or to the mesiolingual (38%) canal [12].

Though the clinical inspection with a naked eye is still widespread, nowadays it is accepted that adequate coronary access, including the use of ultrasonic tips to clean the groove linking the mesiobuccal and mesiolingual canals, and the dental operating microscope are crucial in identifying the accessory mesial canals of lower molars [12].

The mandatory clinical procedure for eliminating the dentin protuberance of the mesial wall and exploring the isthmus on the pulpal floor between the orifices of main mesial canals, mesiobuccal and mesiolingual, could not achieve the expectations for locating the accessory canals without the facilities offered by the dental operating microscope [13].

The operating microscope, unlike the inspection by naked eye or using surgical loupes, allowed locating the small orifice openings and constricted orifices. Similarly, by microscope it was easier to locate the calcified orifices due to the difference in color compared to surrounding dentin and also to recognize the dentin coverage over the canal orifices. Moreover, this dentin coverage that usually occurs in the case of MMC of lower molars can be accurately removed under microscope with an adequate ultrasonic tip [16].

In an *in vivo* study on 75 first and second lower molars Nosrat *et al.* [9] found that 20% of them presented negotiable MMCs and in 60% of molars with a MMC a second distal canal was also located.

By comparing in clinical setting the detection rate of root canal orifices using three different methods, naked eye, surgical loupes, and dental operating microscope, Yoshioka *et al.* [16] found out that the microscopic method detected more exactly the canal orifices than the other two methods. Accordingly, an opinion was advanced that the inspection by naked eye or surgical loupes is relatively ineffective compared to the use of a dental operating microscope.

It was also noticed that the incidence of MMCs decreased with age. In patients aged 20 years or younger, Nosrat *et al.* [9] reported that 32.1% of MMCs were clinically negotiable. According to their study, it seems that the key of identifying and negotiating the MMCs relies upon the magnification and careful tactile inspection of the pulpal floor with a sharp endodontic explorer, and it depends not in the very least on the patient's age.

In a more complex study, de Toubes *et al.* [12] compared *in vitro* four diagnostic methods to detecting accessory mesial canals in lower first molars: clinical inspection, digital radiography, dental operating microscope and CBCT, which is an extra-oral imaging system. A better agreement was found between the dental operating microscope and CBCT in identifying the accessory mesial canals as compared to clinical inspection and digital radiography, which were less accurate.

Even if using the parallax principle and several exposures taken with angle changes of 10–15º, the conventional periapical radiographs do not guarantee the identification of root canals, which are in the same plane [7].

Moreover, since even by using the paralleling technique, serial intra-oral periapical radiographs did not prove to be consistently reproducible, the customized stents bite block was also tried to improve the reliability of image geometry. However, some inconsistencies could not be eliminated and this procedure can also not be used in patients with developing skeleton and dentition [7].

The conventional intraoral periapical radiograph has its inherent limitations in reproducing the morphological details of the complex endodontic system due to the exposure angulation and image contrast, which are not always appropriate [14, 17].

The inherent limitations of conventional radiographs in endodontics are the anatomic noise produced by overlying bone structures that mask the tooth root area of interest and the lack of a 3-D volume of imagistic data [18].

CBCT can overcome the disadvantage of anatomical noise expressed in conventional radiographs by selecting slices that allow separate visualization of the roots in molars without superimposition of the adjacent roots and thick overlying alveolar bone in mandible or zygomatic buttress in maxilla [18].

Developed in the late 1990s, CBCT utilizes an extra-oral imaging scanner. The X-ray beam is cone-shaped and the size of the field of view (FOV) is variable so that the limited volume CBCT scanners may capture a cylindrical or spherical volume of data from a small region of maxilla or mandible, similar in height and width to a conventional intraoral radiograph (40 mm high by 40 mm diameter). Hence, the CBCT with limited FOV is suited for the capture of imagistic data involving no more than one or two neighboring teeth [18].

The tomographic slices may be displayed simultaneously in three orthogonal planes: sagittal, axial, and coronal and the software allows the reconstruction of a new set of orthogonal images in order to assess at any angle the area of interest for diagnosis and treatment planning [18].

Due to the small dimension of voxels, the last generation of CBCT, with limited FOV, has higher image resolution and proved to be suitable for identifying the morphology of the endodontic system [19].

Since the CBCT voxels are equal in length, height and depth (isotropic), unlike the CT voxels, which are anisotropic, they allow in any plane the precise linear measurements of CBCT data regardless of the skull orientation during X-ray exposure [18]. Though it was studied on a small sample of teeth, when using voxel size 75 μm, Michetti *et al.* [20] observed a high correlation between CBCT images and histological sections of roots.

CBCT is a nondestructive method, which enables both *in vivo* and *ex vivo* assessment of root canal anatomy. CBCT is also able to identify additional canals, such as MMC of mandibular molars [21].

CBCT provides more detailed information for adequate endodontic diagnosis and treatment planning than conventional periapical radiograph. Moreover, on CBCT images, the anatomic variations prevalence of root canals system can be simply compared bilaterally [22].

Although the CBCT technology is known since the 1980s, only in the last decade it became an accepted option in endodontics as a diagnostic tool. The main advantages are thought to be the digital imaging and the increasingly detailed information provided by a 3-D image because the isotropic voxels allow accurate measurements in different directions [19].

The main limitations of CBCT images compared with conventional intra-oral radiographs are the poorer resolution and the scattering and beam hardening created by the high density of neighboring structures, such as enamel, or metal restorations and posts [18].

However, in the past few years, because of the technological progress, CBCT proved to be a reliable tool for the proper imagistic investigation in endodontics [14, 17]. Although the periapical radiographs were taken in ortho, mesial and distal angulation, no mesial accessory canal was visualized, whereas the CBCT identified 27% of them [12].

Matherne *et al.* [17] used 72 extracted teeth to compare the diagnostic efficacy of digital radiography with CBCT and found that despite respecting the parallax rule the digital modalities failed to identify one root canal in 36.5% of teeth and at least two canals in 4% of teeth. Their conclusion was that, unlike CBCT, by using digital radiographs some root canals might remain undiscovered.

Regardless of the skill and clinical experience of the endodontist, de Toubes *et al.* [12] reported that for the detection of MMCs the clinical inspection without magnification was less reliable than inspection under dental operating microscope or CBCT.

However, using a dental operating microscope, the number of identified MMCs increased from 27% to 30%. Likewise, an increased number of accessory canals were located by dental operating microscope than those identified by CBCT, 85% vs. 58% [12].

Despite the lower identification rate of MMCs in lower molars using CBCT, this imagistic method is superior to the dental operating microscope because it allows the visualization of the entire canal length, mainly its mid and apical third, whereas the microscope is limited only to the inspection of the straight segment of the root canal [12].

The main advantage of CBCT as a newcomer imagistic tool of investigation is its noninvasive 3-D diagnosing principle for reproducing the internal tooth morphology. Literature pointed out that CBCT, unlike the conventional periapical radiography, is able to identify the complex anatomical features of lower first permanent molars, such as additional root canals and isthmuses.

Though CBCT does not signalize the presence of a more complex morphological configuration of the endodontic system as the micro-CT technology does, since it does not have the same spatial resolution, it is important to note that this commonly used diagnostic tool in clinical setting is capable to identify Vertucci's type I and II root canals [21].

According to previous studies, the prevalence of the MMCs in lower permanent molars ranges from 1–18% [3, 15, 23]. Wang *et al.* [23] recorded by CBCT, in a western Chinese population, a 2.7% incidence of mandibular first molars with three mesial canals. Pomeranz *et al.* [3] and Karapinar-Kazandag *et al.* [15] found the MMC in 7.1% and, respectively, 18% of lower first molars. An increased incidence of 30% was reported by de Toubes *et al.* [12] due to the microscopic inspection.

Silva *et al.* [10] looked for the variation of the root canal system on CBCT images of 234 lower first molars and 226 lower second molars and observed an accessory mesial canal only in 2% of the cases.

de Carvalho & Zuolo [13] found out MMCs in 8.6% out of 93 lower first molars and in only 2.3% out of 111 lower second extracted molars. In their study, the operative microscope increased with 18.6% the number of located MMCs as compared to usual naked eye inspection. Coaxial illumination and magnifications ranging from 3× to 20× are the main characteristics of microscopic examination.

According to the review study of de Pablo *et al.* [6], 52.3% mesial root canals displayed Vertucci type IV and 35% of them Vertucci type II configuration. In 59% of cases, two independent apical foramina were present, in 38.2% one foramen, and in 1.6% three foramina.

The analysis of 3378 distal roots of mandibular molars revealed Vertucci type I configuration (62.7%), type II (14.5%), and type IV (12.4%) configuration. The isthmuses type V configuration occurred on an overall of 1615 teeth in 54.8% of mesial roots and 20.2% of distal roots [6].

The incidence of the MMC in lower permanent molars (type VIII of Vertucci's classification) was found to be 2.6%. The presence of isthmuses as anatomical communications between the canals situated in the same root of lower permanent molars is considered a normal issue rather than an abnormality. The incidence of type V isthmuses in the mesial root of lower first molars may range from 23% to 77.4% and in the distal root between 8–55% [6].

Plotino *et al.* [22] found out in 34 patients that 70.6% of lower first molars and 81% of lower second molars showed a perfect symmetry of the endodontic system. The symmetry of root canal morphology, when treating two opposite teeth in the same patient, is of paramount importance for a successful clinical outcome since their internal anatomy might be different. Accordingly, since around 30% of first molars and 20% of second molars might have asymmetric variations, care should be taken when bilaterally treating same mandibular molar in a patient.

Since radiographic examination is crucial in endodontics, nowadays CBCT is a valuable imagistic tool for diagnostic and treatment planning [19]. The benefits of CBCT as an investigation tool in the diagnosis and planning of endodontic treatment aiming to bring together an adequate amount of information has to prevail over any potential risks of ionizing radiation [18].

Conclusions

This study performed on a Romanian population by using CBCT scans evaluated the presence of the MMC in 144 mandibular first permanent molars and 140 mandibular second permanent molars. The incidence of MMC ranged from 5.67% in first molars to 4.28% in second molars. The occurrence of MMC in mandibular first molars was associated in all cases of our study with a second distal canal, unlike the mandibular second molars where the MMC was associated with only one distal canal. With the limitations of this study, it is worthy to consider the patient gender when performing the preoperative evaluation since the male/female ratio of MMC was 1:3 in mandibular first molars and 5:1 in mandibular second molars.

Conflict of interests

The authors deny any conflict of interests related to this study.

Author contribution

Anca Nicoleta Temelcea has equal contributions to this paper as the first author.

References

[1] Cleghorn BM, Goodacre CJ, Christie WH. Morphology of teeth and their root canal systems. In: Ingle JI, Bakland LK, Baumgartner JC (eds). Ingle's endodontics. 6th edition, BC Decker, Hamilton, Ontario, 2008, 151–220.

[2] Zhang R, Wang H, Tian YY, Yu X, Hu T, Dummer PM. Use of cone-beam computed tomography to evaluate root and canal morphology of mandibular molars in Chinese individuals. Int Endod J, 2011, 44(11):990–999.

[3] Pomeranz HH, Eidelman DL, Goldberg MG. Treatment considerations of the middle mesial canal of mandibular first and second molars. J Endod, 1981, 7(12):565–568.

[4] Fabra-Campos H. Three canals in the mesial root of mandibular first permanent molars: a clinical study. Int Endod J, 1989, 22(1):39–43.

[5] Fabra-Campos H. Unusual root anatomy of mandibular first molars. J Endod, 1985, 11(12):568–572.

[6] de Pablo OV, Estevez R, Péix Sánchez M, Heilborn C, Cohenca N. Root anatomy and canal configuration of the permanent mandibular first molar: a systematic review. J Endod, 2010, 36(12):1919–1931.

[7] Patel S, Dawood A, Whaites E, Pitt Ford T. New dimensions in endodontic imaging: Part 1. Conventional and alternative radiographic systems. Int Endod J, 2009, 42(6):447–462.

[8] Patel S, Dawood A, Pitt Ford TP, Whaites E. The potential applications of cone beam computed tomography in the management of endodontic problems. Int Endod J, 2007, 40(10):818–830.

[9] Nosrat A, Deschenes RJ, Tordik PA, Hicks ML, Fouad AF. Middle mesial canals in mandibular molars: incidence and related factors. J Endod, 2015, 41(1):28–32.

[10] Silva EJ, Nejaim Y, Silva AV, Haiter-Neto F, Cohenca N. Evaluation of root canal configuration of mandibular molars in a Brazilian population by using cone-beam computed tomography: an *in vivo* study. J Endod, 2013, 39(7):849–852.

[11] Corcoran J, Apicella MJ, Mines P. The effect of operator experience in locating additional canals in maxillary molars. J Endod, 2007, 33(1):15–17.

[12] de Toubes KM, Côrtes MI, Valadares MA, Fonseca LC, Nunes E, Silveira FF. Comparative analysis of accessory mesial canal identification in mandibular first molars by using four different diagnostic methods. J Endod, 2012, 38(4):436–441.

[13] de Carvalho MCC, Zuolo ML. Orifice locating with a microscope. J Endod, 2000, 26(9):532–534.

[14] La SH, Jung DH, Kim EC, Min KS. Identification of independent middle mesial canal in mandibular first molar using cone-beam computed tomography imaging. J Endod, 2010, 36(3):542–545.

[15] Karapinar-Kazandag M, Basrani BR, Friedman S. The operating microscope enhances detection and negotiation of accessory mesial canals in mandibular molars. J Endod, 2010, 36(8): 1289–1294.

[16] Yoshioka T, Kobayashi C, Suda H. Detection rate of root canal orifices with a microscope. J Endod, 2002, 28(6):452–453.

[17] Matherne RP, Angelopoulos C, Kulid JC, Tira D. Use of cone-beam computed tomography to identify root canal systems *in vitro*. J Endod, 2008, 34(1):87–89.

[18] Patel S. New dimensions in endodontic imaging: Part 2. Cone beam computed tomography. Int Endod J, 2009, 42(6):463–475.

[19] Cotton TP, Geisler TM, Holden DT, Schwartz SA, Schindler WG. Endodontic applications of cone-beam volumetric tomography. J Endod, 2007, 33(9):1121–1132.

[20] Michetti J, Maret D, Mallet JP, Diemer F. Validation of cone beam computed tomography as a tool to explore root canal anatomy. J Endod, 2010, 36(7):1187–1190.

[21] Ordinola-Zapata R, Bramante CM, Versiani MA, Moldauer BI, Topham G, Gutmann JL, Nuñez A, Duarte MA, Abella F. Comparative accuracy of the clearing technique, CBCT and micro-CT methods in studying the mesial root canal configuration of mandibular first molars. Int Endod J, 2017, 50(1):90–96.

[22] Plotino G, Tocci L, Grande NM, Testarelli L, Messineo D, Ciotti M, Glassman G, D'Ambrosio F, Gambarini G. Symmetry of root and root canal morphology of maxillary and mandibular molars in a white population: a cone-beam computed tomography study *in vivo*. J Endod, 2013, 39(12):1545–1548.

[23] Wang Y, Zheng QH, Zhou XD, Tang L, Wang Q, Zheng GN, Huang DM. Evaluation of the root and canal morphology of mandibular first permanent molars in a western Chinese population by cone-beam computed tomography. J Endod, 2010, 36(11):1786–1789.

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