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THE INCIDENCE OF UNFILLED SECOND MESIOBUCCAL CANALS AND PERIAPICAL LESIONS IN MAXILLARY MOLARS BY CONE-BEAM COMPUTED TOMOGRAPHY E-VOL DX SOFTWARE

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Abstract
This study evaluated the incidence of unfilled second mesiobuccal (MB2) canals and periapical lesions in first maxillary molars using CBCT e-Vol DX software. Hence, 326 CBCT images of first maxillary molars of patients undergoing endodontic treatment were selected. The e-Vol DX software performed a retrospective review of these images, recording the presence or absence of MB2 canals, filling, and periapical lesions in first maxillary molars. Specific statistical analysis was performed at a 5% significance level. Unfilled MB2 canals were highly frequent in first maxillary molars and significantly associated with periapical lesions in the mesiobuccal root of these teeth ($p<0.05$). The CBCT e-Vol DX software effectively detected MB2 canals, and unfilled canals may be associated with periapical lesions.

Keywords: CBCT. E-Vol. Maxillary molar. MB2 canal. Mesiobuccal canal. Mesiopalatal canal.

1. Introduction

The root canal system shows several anatomical variables and complexities, corresponding to favorable bacterial colonization and proliferation spaces, complicating their elimination through intracanal decontamination procedures (Byström and Sundqvist 1981). Although most microorganisms are located in the primary canal, they may also occur in the depth of dentinal tubules or ramifications, cement gaps (Shovelton 1964), the periapical region (Nair et al. 1990), or in undetected root canals during the first endodontic intervention (Betancourt et al. 2015).

The scientific literature shows that many teeth do not respond to endodontic treatment because procedural errors prevent controlling intracanal infections (Lin et al. 2005). Maxillary molars are the most commonly treated teeth and have the highest failure frequency because of undetected second mesiobuccal (MB2) root canals (Shah et al. 2014). Thus, numerous studies have analyzed MB2 canals in maxillary molars, and such detection is essential as they may occur in 37%-96% of cases (Degerness and

Bwles 2010). Additionally, undetected and untreated canals may indicate microorganism permanence and endodontic treatment failure (Betancourt et al. 2015). Therefore, understanding the internal dental anatomy and MB2 canal detection in maxillary molars is essential.

Cone-beam computed tomography (CBCT) provides three-dimensional images of dental elements and their anatomical complexities, presenting excellent image resolution and using a relatively low radiation dose (American Association of Endodontics 2011). This method also offers different applications in dentistry and endodontics (Patel et al. 2007). Weissman et al. (2015) state that CBCT images provide higher sensitivity and specificity than conventional radiographs. The same authors identified apical radiolucencies in all patients reporting localized swelling (71% visible on both PA and CBCT imaging and 29% only on CBCT). Conversely, 26% of patients without localized swelling did not identify apical radiolucencies but were visible on both modalities in 53% of cases and only on CBCT imaging in 21% of cases. Comparisons with periapical and panoramic radiographs showed that CBCT increases diagnostic accuracy (Estrela et al. 2008). As an example of radiographic limitation, conventional radiographs detect artificial lesions in cadavers only in the presence of perforation, extensive bone cortex destruction on the outer surface, or cortical bone erosion from the inner surface. Lesions confined within the cancellous bone cannot be detected, whereas lesions with buccal and lingual cortical involvement produce distinct radiographic rarefaction areas (Bender and Seltzer 1961). Other conditions, such as apical morphologic variations, surrounding bone density, X-ray angulations, and radiographic contrast, influence radiographic interpretation (Halse et al. 2002). Therefore, endodontic treatment aided by CBCT becomes more predictable (Scarfe et al. 2007).

Several CBCT devices have been recently developed, along with specific software. That is because original CBCT images may not be suitable for visualization, as they may be blurred, unclear, and present artifacts. Thus, these images require numerous adjustments to improve visualization quality (Bueno et al. 2018). Regarding this need, e-Vol DX software (CDT Software, Bauru, SP, Brazil) was developed with several resources to improve image quality, such as brightness and contrast adjustments, image thickness control, image sharpening, and noise reduction. Moreover, different CBCT devices may automatically recognize data, decreasing the time for browsing and capturing high-resolution images (Bueno et al. 2018).

Considering this scenario and the scarcity of data in the literature on the topic and specific software, this study evaluated the incidence of unfilled MB2 and periapical lesions in first maxillary molars using CBCT e-Vol DX software. The hypotheses were: (i) there is a significant incidence of unfilled MB2, (ii) there is a relationship between undetected and unfilled MB2 with periapical lesions in the mesiobuccal root of first maxillary molars, and (iii) CBCT e-Vol DX software is a relevant resource for diagnosing these cases.

2. Material and Methods

This study complies with norms established by the Research Ethical Committee of the University of Passo Fundo, RS, Brazil, and was approved by protocol 5.971.182. It is a retrospective study that surveyed electronic medical records from a private radiology clinic in Passo Fundo, RS, Brazil. These records provided CBCT scans of patients who sought the radiology service between January 2017 and January 2022 and were analyzed to identify endodontic treatment in the first right and the first left maxillary molars. Cases were selected according to the inclusion and exclusion criteria, totaling 326 evaluated cases.

The inclusion criteria consisted of patients submitted to clinical and tomographic examinations as part of their regular care or evaluation in a private clinic. All included cases underwent endodontic treatment in a first maxillary molar with definitive crown restoration. The exclusion criteria were patients not yet submitted to endodontic treatment in a first maxillary molar and with completed endodontic therapy in a first maxillary molar without definitive crown restoration or with provisional crown restoration.

The selected cases were not submitted to additional clinical examination or procedure, and the selected patients in the electronic medical records were not involved with the research, as all data remained confidential. All CBCT images were obtained using a Kodak 9000 device (Eastman Kodak Co., Rochester, NY, USA) with the following parameters: 74 kV and 10 mA, FOV 50 x 37 mm, and voxel of 0.076

mm³. Images were acquired in the DICOM format, processed in e-Vol DX software (CDT Software, Bauru, SP, Brazil), and projected on an LED screen (Sony, Minato, Japan) for data analysis and recording.

The study verified coronal, sagittal, and axial sections. First, sagittal and coronal sections were placed parallel to the long root axis, and axial sections were obtained at 0.5mm intervals and 1 mm of thickness for all samples, using multiplanar reformatting. This feature builds a three-dimensional model and shows all structures superimposed within 1 mm of thickness. The crown-apex direction was explored to record the MB2 canal, the presence or absence of MB2 canal filling, and periapical lesions associated with the root apex. A radiolucent image surrounding the root apex with a diameter larger than 2 mm determined periapical lesions, and e-Vol software established this measurement. The first maxillary molar side and patients' sex and age were also recorded. A previously calibrated examiner with technical and academic training in imageology and extensive experience evaluated the CBCT images.

Regarding the statistical analysis, counts and percentages described the categorical data. Mean and standard deviation determined the quantitative data. Chi-square or Fisher's exact tests compared the counts. The relative risk (RR) of 95% confidence intervals was also obtained. Values of $p<0.05$ were statistically significant. The analyses used IBM-SPSS software (Armonk, NY, USA).

3. Results

Table 1 shows the data on MB2 canal incidence in first maxillary molars and its distribution according to tooth side and patients' sex and age. The CBCT e-Vol DX software identified MB2 canals in 66.9% of cases (218/326). The percentage distribution of the MB2 canal according to the side was homogeneous, occurring in 48.1% of cases on the right side (105/218) and 51.9% on the left side (113/218) without statistically significant differences ($p>0.05$). The incidence of MB2 canal according to sex showed statistically significant differences ($p<0.05$), with 66.1% occurring in women (144/218) and 33.9% in men (74/218). The average age of study subjects with an MB2 canal was 45.2 ± 15.5 years.

Table 1. MB2 canal incidence in first maxillary molars and distribution according to tooth side and patients' sex and age.

Total sample	MB2 canal incidence % (number)	Side % (number)		Sex % (number)		Average age ± SD
		Right	Left	Male	Female	
n = 326	66.9% (218/326)	48.1% (105/218)	51.9% (113/218)*	33.9% (74/218)	66.1% (144/218)**	45.2 ± 15.5

*in the row, $p > 0.05$; ** in the row, $p < 0.05$.

Table 2 shows the data on the incidence of MB2 canal filling in first maxillary molars and periapical lesions in the mesiobuccal root of the same teeth. Only 16.5% of cases (36/218) had a filled MB2 canal, and 83.5% (182/218) had an unfilled MB2 canal, with statistically significant differences ($p<0.05$). Figure 1 reveals a filled MB2 canal in first maxillary molars, and Figure 2 shows an unfilled MB2 canal in the same teeth.

Table 2. MB2 canal filling incidence in first maxillary molars and periapical lesions.

MB2 canal incidence	Filling % (number)	Lesion % (number)	RR (95% CI)	p
n = 218	Yes – 16.5% (36/218)	19.4% (7/36)	-	-
	No – 81.5% (182/218)**	80.8% (147/182)**	4.15 (2.13-8.11)	< 0.001

** in the column, $p < 0.05$.

Filled MB2 canals appeared in 36 cases, with 19.4% showing periapical lesions (7/36), while unfilled MB2 canals occurred in 182 cases, with 80.8% presenting periapical lesions (147/182). Figure 3 shows a periapical lesion in the mesiobuccal root of a first maxillary molar with MB2 canal filling, and Figure 4 shows a periapical lesion with unfilled MB2 canal. Therefore, an undetected and unfilled fourth canal had a statistically significant relationship with the periapical lesion in the mesiobuccal root of first maxillary molars ($p<0.05$).

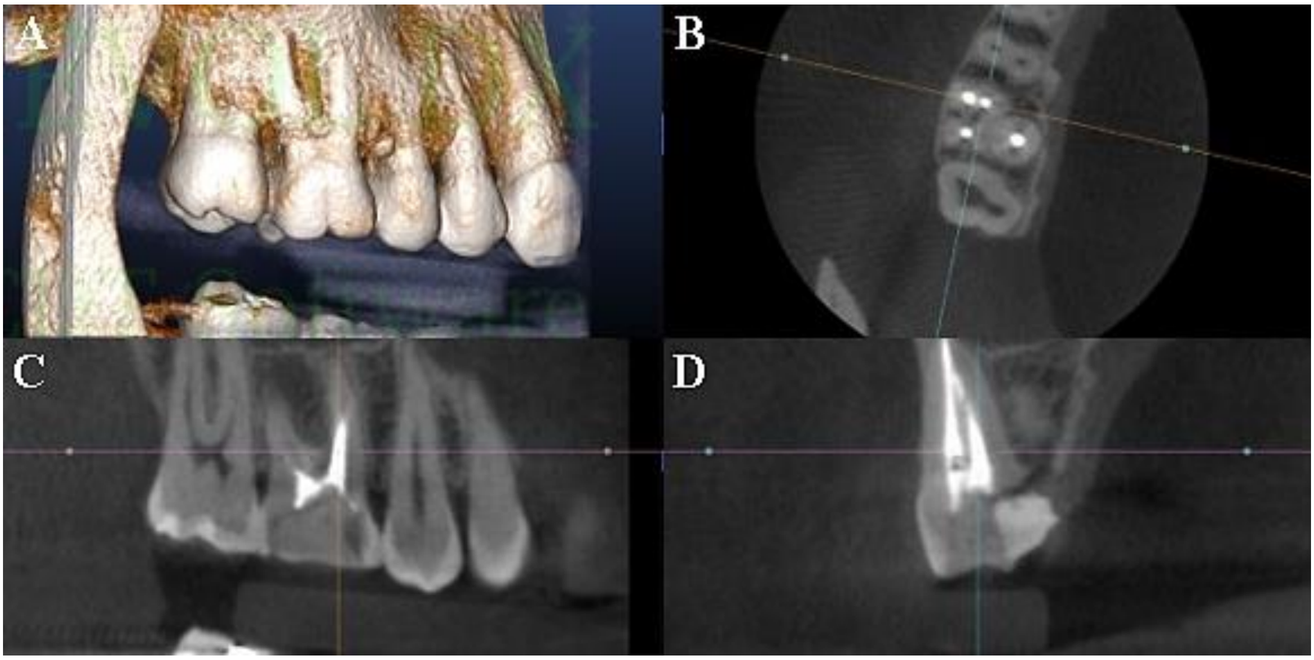

Figure 1. Representative images of CBCT e-Vol DX software showing a filled MB2 canal in the first maxillary molar. A - 3D volumetric reconstruction; B - Axial section; C - Coronal section; D -Sagittal section.

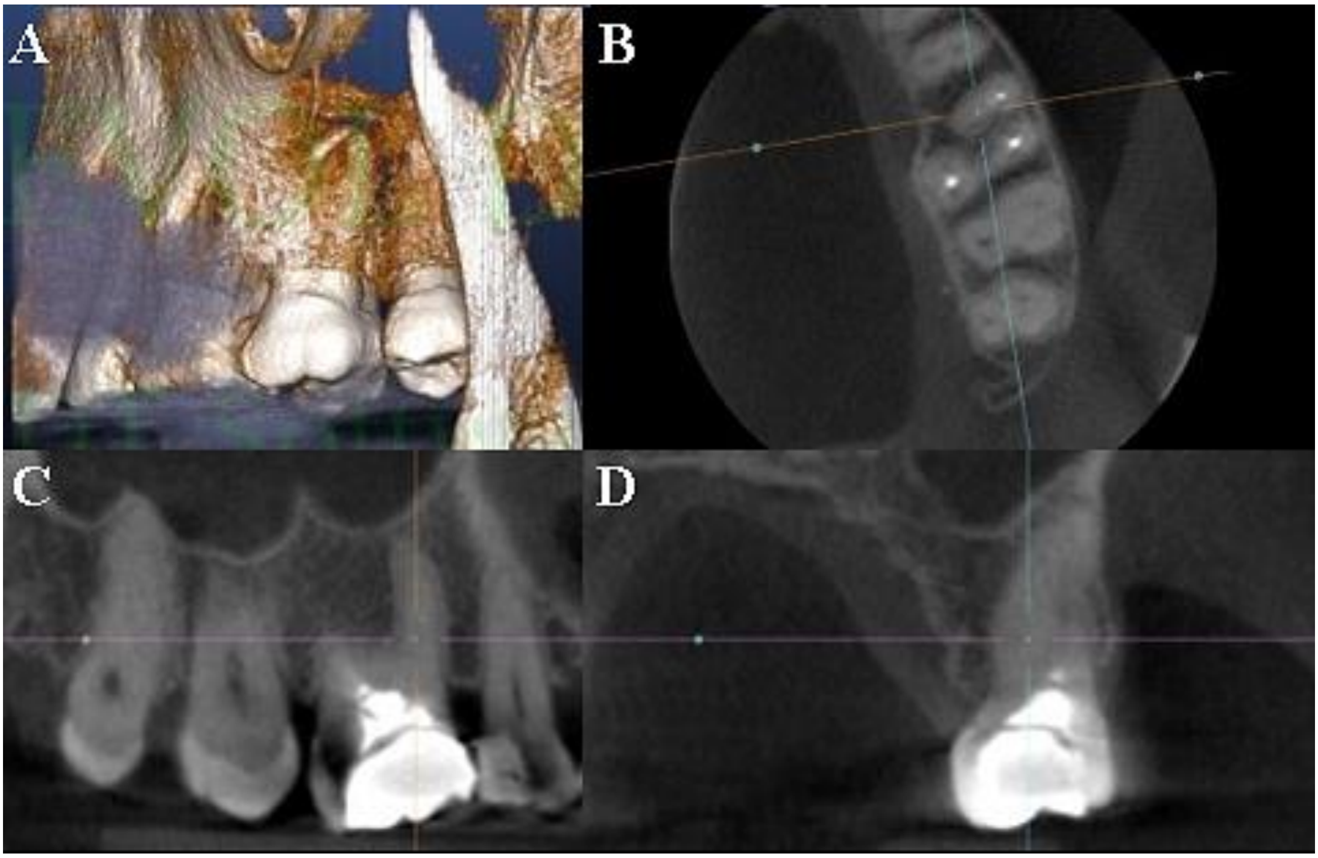

Figure 2. Representative images of CBCT e-Vol DX software showing an unfilled MB2 canal in the first maxillary molar. A - 3D volumetric reconstruction; B - Axial section; C - Coronal section; D - Sagittal section.

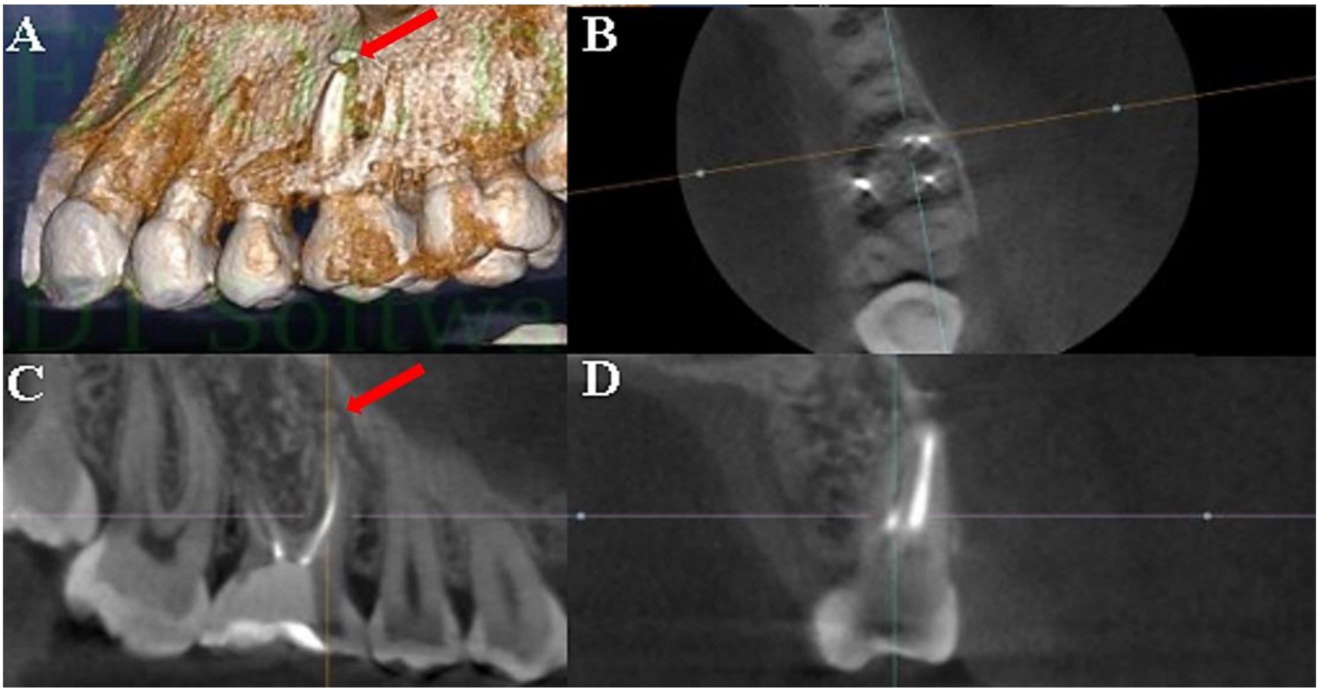

Figure 3. Representative images of CBCT e-Vol DX software showing a periapical lesion in the mesiobuccal root of a first maxillary molar with a filled MB2 canal (red arrows). A - 3D volumetric reconstruction; B - Axial section; C - Coronal section; D - Sagittal section.

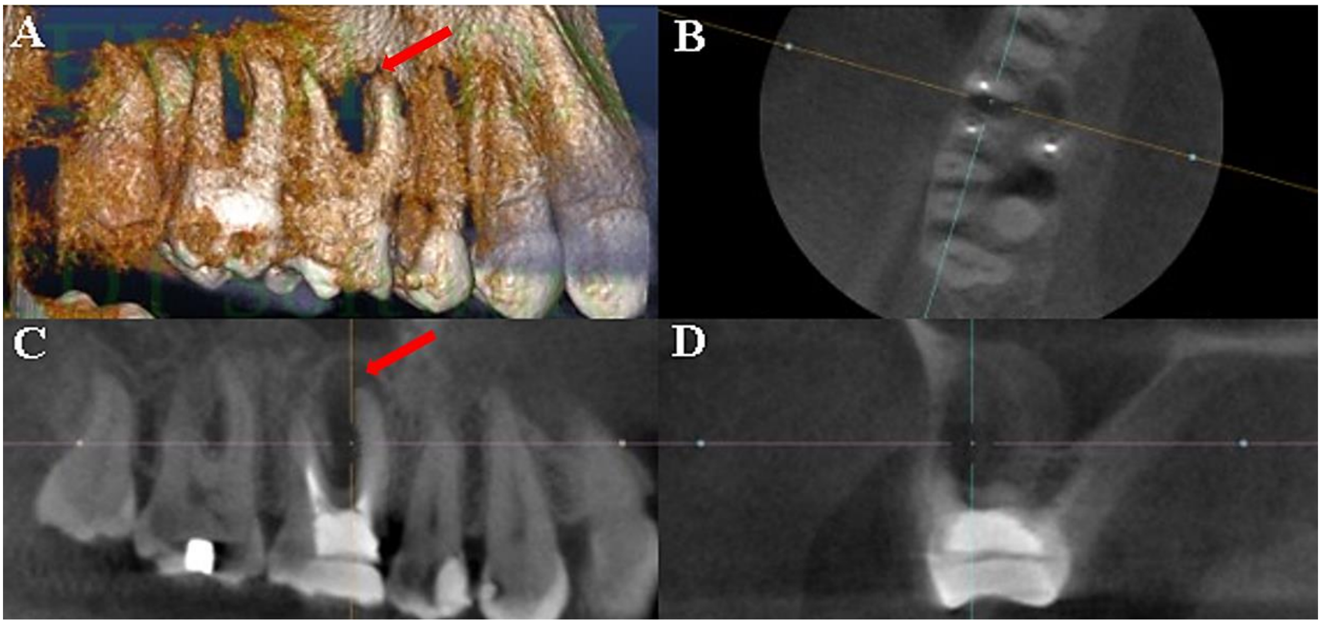

Figure 4. Representative images of CBCT e-Vol DX software showing a periapical lesion in the mesiobuccal root of a first maxillary molar with an unfilled MB2 canal (red arrows). A - 3D volumetric reconstruction; B - Axial section; C - Coronal section; D - Sagittal section.

4. Discussion

This study showed a high MB2 canal incidence in first maxillary molars and a significant incidence of unfilled canals, confirming the first hypotheses of the present study. That means the clinician or endodontist performed conventional endodontic treatment and did not locate and/or treat the MB2 canal. CBCT effectively detected the MB2 canal (Matherne et al., 2008). However, such detection is as relevant as clinically locating this anatomical variation because it may cause infection persistence and endodontic treatment failure if not accessed, treated, and filled (Estrela et al. 2008). Clinical conditions reported 93% of MB2 canal detection when associating microscopy with ultrasonic tips (Alçam et al. 2008). Therefore, these resources are essential for adequate access to the MB2 canal, favoring its chemomechanical preparation and filling.

The MB2 canal was detected in 66.9% of cases (218/326), confirming the third hypothesis of the present study and agreeing with previous research where MB2 canal incidence in first maxillary molars occurred in 65%-70% of cases using CBCT software (Lee et al. 2011; Kim et al. 2012; Betancourt et al. 2015; Betancourt et al. 2016). In this scenario, the MB2 canal has a significant tendency to occur bilaterally in first maxillary molars, with detection on the right and left sides in the same patient (Lee et al. 2011; Betancourt et al. 2015; Betancourt et al. 2016). Thus, when the MB2 canal is in a maxillary molar on one side, its presence in the first maxillary molar on the opposite side must be considered. Such findings agree with the present study, where the MB2 canal in an endodontically treated first maxillary molar on the right side also appeared on the left side. The percentage distribution of the MB2 canal according to the side was also homogeneous on both sides, showing that the MB2 canal appears constantly in maxillary molars.

MB2 canal incidence in first maxillary molars was more frequent in women than men. Other studies demonstrated higher incidence in men (Fogel et al. 1994) or similar incidence in both sexes (Zheng et al. 2010). Demineralization and bone loss in adults may be up to three times higher in women than in men, potentially interfering with the contrast feature of CBCT software and complicating MB2 canal detection (Benson et al. 1991). However, this study did not make this observation. Differences in the population characteristics comprising the sample of studies may help explain this difference in results.

Age may interfere with MB2 canal detection in first maxillary molars, especially in older patients. Over time, mineral tissue deposits increase, and this root canal may obliterate or completely calcify. Reactive dentin production from restorative procedures, trauma, and/or stress may also interfere with detecting this anatomical variation (Qualtrough and Manocci 2011). Furthermore, with advanced age, cortical bone porosity also increases, causing image radiolucency and making it hard to contrast with the MB2 canal (Hildebolt 1997). The present study made this observation. The sample consisted of individuals with a minimum age of 15 and a maximum age of 83. Although the mean age was around 45, there were a few samples of individuals over 60.

First permanent maxillary molars are the dental elements with the most anatomical complexities in the root canal system (Zheng et al. 2010). Hence, the highest rates of endodontic treatment failure occur in these teeth, mainly because of the inability to detect the MB2 canal (Zhang et al., 2011). Simultaneously, endodontic treatment failure presents extremely resistant bacteria that survive or are unaffected by intracanal decontamination procedures from the moment they settle and proliferate in complex areas of the root canal system (Ran et al. 2015). Consequently, bacteria colonize this space, propagate, and progress toward the periapical region, developing pathological lesions and bone tissue degradation (American Association of Endodontics 2011). Thus, the MB2 canal must be detected, cleaned, and filled in maxillary molars to effectively eliminate microorganisms and achieve higher rates of endodontic treatment success.

More than 80% of endodontically treated MB2 canals in first maxillary molars in this study were unfilled. Furthermore, over 80% of these cases were associated significantly with periapical lesions. These findings confirm the second hypothesis of the present study and show the relevance of CBCT for detecting the MB2 canal in maxillary molars. Moreover, resources that enable MB2 canal access, adequate chemomechanical preparation, and effective filling of this anatomical variation are also required for adequately planning the endodontic treatment. Chemomechanical preparation will help effectively clean the root canal system, and filling will ensure the hermetic sealing of this space (Silva et al., 2016). Thus, favorable conditions are created for repairing and healing regions affected by pathological changes of endodontic origin.

A periapical lesion was detected in almost 20% of cases even in filled MB2 canals in the first maxillary molars of the present study. That demonstrates the deficiency of chemomechanical preparation in these situations. The evolution of endodontic tools made the instrumentation technique faster. Concomitantly, these instruments do not reach a significant root canal area (Vaudt et al., 2009), and the contact time of auxiliary chemical substances with root canal walls significantly decreases, reducing the antimicrobial properties of these substances (Souza et al. 2018). Thus, complementary decontamination resources should be considered to reduce the microbial load effectively and contribute to endodontic treatment success, unlike cases with periapical lesions in filled MB2 canals.

Anatomically, the MB2 canal may appear in different places in first maxillary molars, and the mesiobuccal (MB) canal is a reference location. Previous studies have located the MB2 canal from 1 to 3 mm palatally and less than 1 mm medially related to the MB canal using CBCT resources (Betancourt et al. 2015; Betancourt et al. 2016). CBCT effectively detected the MB2 canal in maxillary molars (Lee et al. 2011; Betancourt et al. 2015; Betancourt et al. 2016), and it is more efficient than conventional radiographs (Matherne et al. 2008). In turn, e-Vol DX software presents several tools and filters that allow more precise navigation through anatomical structures, artifact removal, isolation of structures for evaluation, and high resolution and sharpness of acquired images (Bueno et al. 2018). Hence, the present study used CBCT e-Vol DX software to detect MB2 canals in maxillary molars, identify whether these root canals have been treated, and show the relationship with periapical lesions.

The present study has some limitations. Perhaps the most significant one is the retrospective design using a database. Therefore, data before and after endodontic treatment using CBCT could not be compared, analyzing the incidence of undetected and untreated MB2 canals and their relationship with periapical lesions. However, the incidence of undetected and untreated MB2 canals in a large sample could be analyzed by verifying periapical lesions in most cases. This study also evaluated the relationship between cases where MB1 and MB2 canals join in the periapical region, the presence or absence of lesions, and the quality of MB1 treatment. The potential diagnosis between the different e-Vol software filters_could also be compared. Among other limitations, these variables emerge as perspectives for evaluation in future studies.

5. Conclusions

Considering the study limitations, CBCT e-Vol DX software effectively helped to detect the MB2 canal. Such canals are highly frequent in the anatomy of first maxillary molars, and unfilled canals may be associated with periapical lesion induction or progression.

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Ethics Approval: The present study complies with norms established by the Research Ethical Committee of the University of Passo Fundo and was approved by the protocol 5.971.182.

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