

# Morphology of Mesiobuccal Root Canals of Maxillary First Molars: a comparison of CBCT scanning and Cross-sectioning

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The aim of this study was to evaluate the mesiobuccal root of maxillary first molars, according to the root canal configuration, prevalence and location of isthmuses at 3 and 6 mm from the apex, comparing cone-beam computed tomography (CBCT) analysis and cross sectioning of roots by thirds. Images of the mesiobuccal root of 100 maxillary first molars were acquired by CBCT and then roots were cross-sectioned into two parts, starting at 3 mm from the apex. Data were recorded and analyzed according to Weine's classification for root canal configuration, and Hsu and Kim's classification for isthmuses. In the analysis of CBCT images, 8 root canals were classified as type I, 57 as type II, 35 as type III. In the cross-sectioning technique, 19 root canals were classified as type I, 60 as type II, 20 as type III and 1 as type IV. The classification of isthmuses was predominantly type I in both CBCT and cross-sectioning evaluations for sections at 3 mm from the apex, while for sections at 6 mm from the apex, the classification of isthmuses was predominantly types V and II in CBCT and cross-sectioning evaluations, respectively. The cross-sectioning technique showed better results in detection of the internal morphology of root canals than CBCT scanning.

Key Words: cone-beam computed tomography, maxillary first molars, second mesiobuccal canal, morphology, root canal system.

## Introduction

The aim of the endodontic treatment is to disinfect the root canal system, which is achieved by the chemical-mechanical action of instruments, use of irrigating solutions, temporary dressing and finishing with three-dimensional filling materials inert to the living tissue (1). Its success, however, relies on the knowledge of the internal dental anatomy of the treated tooth and its anatomical variations. The ability to find all canals is also a determining factor for the treatment success, and according to Baratto Filho et al. (2), anatomical variations in the root canal system have contributed to failures of the results.

Among all tooth groups, maxillary molars have the most complex morphology. The mesiobuccal roots of maxillary molars show greater variation in their root canal system than distobuccal and palatine roots (3). Some authors claim that the failure rates in the endodontic treatment of maxillary first molars are due to the presence of a second canal in the mesiobuccal root (MB2) that cannot be detected, debrided and filled (4). According to Hartwell et al. (5) the incidence of MB2 canals in maxillary first molars is between 40 and 95%. Similar results were obtained by Baratto Filho et al. (2), who observed in an *ex vivo* evaluation that 67.14% of maxillary first molars exhibited MB2 canal. Professionals should be aware of anatomical variations during all phases of the endodontic diagnosis and treatment, since such variations in root canal

morphology of maxillary first molars are very common (6).

Anatomical structures such as isthmuses and accessory canals also cooperate to failures of the endodontic treatment, as they can act as reservoirs of bacteria and necrotic pulp tissues (7). According to Weller et al. (8), an isthmus is defined as a narrow ribbon-shaped communication between two root canals containing pulp tissue. The incidence of isthmuses in mesiobuccal roots of maxillary first molars ranges from 5 to 53%, higher at 3-5 mm from the apex (9). With technological advances, different techniques have been developed to facilitate endodontic treatment. Expansion of the visual field obtained using the operating microscope in clinical practice may facilitate the location and treatment of additional canals. Another useful means for diagnosing endodontic problems is the cone-beam computed tomography (CBCT), which allows three-dimensional visualization of images, assisting in the identification of anatomical features and variations in the root canal system (2).

The purpose of this study was to classify, according to CBCT scanning and cross-sectioning technique of root by thirds, the mesiobuccal root of maxillary first molars, according to the canal configuration (10) and isthmuses (9) in the final millimeters of the root.

## Material and Methods

### *Collection and Preparation of Samples*

After approval of the study protocol by the local Ethics Committee (038554/2014), 100 maxillary first molars, which had fully formed mesiobuccal root, no endodontic treatment and no root resorption were selected. Teeth with fused roots or root anatomy with severe alterations were excluded from the study.

Coronal opening was performed with carbide bur # 2 (KG Sorensen, São Paulo, SP, Brazil) and the roof of the pulp chamber was removed with Endo Z bur (Dentsply Maillefer, Ballaigues, Vaud, Switzerland) at high rpm and under refrigeration. Then, the teeth were inserted into two colorless rectangular acrylic plates (210x110x5.0 mm) with rows arranged by numbers (1 to 10) and lines by letters (A, B, C, D, E, F, G, H, I, J) for identification. The teeth were arranged in five rows of ten teeth on each plate, with buccolingual and mesiodistal axes arranged in the same direction. The apexes of mesiobuccal roots were positioned at the same level in order to ensure positioning during CT scan. Distobuccal and palatal roots were removed to facilitate the evaluations.

### CBCT Analysis

The acrylic plates were placed on the Cone-Beam I-Cat CT scanner (Imaging Sciences International, Hatfield, PA, USA) with 120 Kv, 46.72 mA. The scanning parameters were: acquisition time of 40 s, small field of view (FOV=6.0 cm), voxel 0.2 mm, matrix of 800 by 800 pixels. Crude data were processed by Xoran-Cat software (Imaging Sciences International), so that 394 sections were obtained in the axial plane, which generated 8.97 MB files in DICOM format.

The CBCT images were analyzed by the Cyclops MedStation software (<http://www.telemedicina.ufsc.br/cms/index.php?lang=en>) in absence of light. The images were observed in transverse sections at 3 and 6 mm from the apex to analyze the type of root canal configuration and the prevalence and location of isthmuses.

In the tomographic evaluation, the number and types of root canals present in the mesiobuccal root were determined according to the Weine's classification (10): type I, a single canal from the pulp chamber to the apex; type II, 2 canals coming out from the pulp chamber that converge to a canal at the apex; type III, 2 distinct canals that begin at the chamber and end at the apex in independent foramina; and type IV, 1 canal that comes out from the pulp chamber and bifurcates into two canals before ending in independent apical foramina.

The images were also used to classify isthmuses, whenever present, based on Hsu and Kim (9): type I, occurrence of 2 or 3 canals without significant communications between them; type II, when there is definite connection between 2 main canals; type III where there is a third canal between two main canals, all connected by a definite connection;

type IV, when the main canals project into the isthmus; and type V, recognized as a true connection or open corridor between the main canals along the section. When there was no isthmus, the classification was considered zero.

### Cross-sectioning and Clinical Analysis of the Mesiobuccal Root

After CBCT scanning, the roots were cross-sectioned into two parts using a super-fine grain stainless steel disc (Dhpro, Paranaguá, PR, Brazil) with synthetic diamond, mounted on a straight piece (Kavo Intramatic, Joinville, SC, Brazil). The mesiobuccal roots were sectioned from the apical third (final 3 mm) (Fig. 1). Each sectioned root was individually separated and placed in labeled and identified plastic containers.

The presence of MB2 canal and the presence and type of isthmuses in maxillary first molars was performed using 3.5x magnifying lens and Flexo-File #06, #08 and #10 files (Dentsply Maillefer). Each slice was examined and the data were interpreted according to the Weine's classification (10) for root canal configuration and Hsu and Kim's classification for isthmus configuration (9).

The cross-sectioning technique by thirds was used to confirm the presence of MB2 canal, the canal configuration and the classification of isthmuses. A single calibrated examiner performed all analyses. The reproducibility of diagnostic tests was evaluated by the kappa test (kappa value=0.85).

### Data Analysis

Data were recorded and analyzed by the Statistical Package for Social Sciences 20.0 (SPSS Inc., Chicago, IL, USA) software. The behavior of all variables was descriptively analyzed. The diagnostic agreement between groups was tested by the Cohen Kappa test, with a significance level of 5% ( $\alpha=0.05$ ).

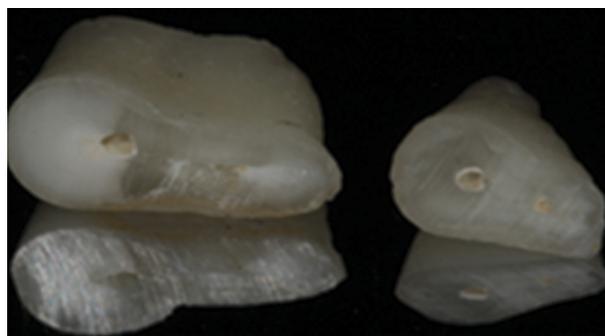


Figure 1. Cross section at 6 and 3 mm from the apex of the mesiobuccal root of a maxillary first molar classified as type III (according to Weine's classification for canal configuration) and type II (according to Hsu and Kim's classification for isthmus configuration).

## Results

### Percentage of Canal Types According to Weine's Classification

Root canals evaluated by CBCT and in cross-sections are shown in Table 1. It was observed that in the cross-sectioning technique, 19% of mesiobuccal roots showed a single canal (type I according to Weine's classification) and 81% had a second canal (MB2), and out of them, 60% were classified as type II, 20% as type III, and 1% as type IV. In the analysis of CBCT images, only 8% of roots had one canal, classified as type I. Ninety-two percent of roots showed MB2 canal, and out of them, 57% were classified as type II and 35% as type III.

### Percentage of Presence of Isthmus at 3 and 6 mm from the Apex in CBCT and Sectioning by Thirds

Table 1. Configuration of the root canal(s) of mesiobuccal roots of maxillary first molars (n=100) according to Weine's classification and configuration of the isthmuses according to Hsu and Kim's classification, in the CBCT and cross-sectioning analysis

Classification	CBCT		Cross-section	
	n	%	n	%
Root canal	8	8.0	19	19.0
Type I	57	57.0	60	60.0
Type II	35	35.0	20	20.0
Type III	-	-	1	1.0
Type IV	-	-	-	-
Isthmus at 3 mm	64	64.0	79	79.0
No isthmus	13	13.0	16	16.0
Type I	12	12.0	5	5.0
Type II	2	2.0	-	-
Type III	1	1.0	-	-
Type IV	8	8.0	-	-
Type V	-	-	-	-
Isthmus at 6 mm	34	34.0	46	46.0
No isthmus	14	14.0	15	15.0
Type I	14	14.0	16	16.0
Type II	3	3.0	4	4.0
Type III	2	2.0	6	6.0
Type IV	33	33.0	13	13.0
Type V	8	8.0	19	19.0

In the analysis of each third sectioned from the mesiobuccal root at 3 mm from the apex, isthmuses were found in 21% of roots, and out of them, 16% were classified as type I and 5% as type II. At 6 mm from the apex, it was found that 54% of roots showed isthmuses. Out of them, 15% were classified as type I, 16% as type II, 4% as type III, 6% as type IV and 13% as type V. In the tomographic evaluation of images at 3 mm from the apex, isthmuses were found in 36% of mesiobuccal roots, and at 6 mm from the apex, isthmuses were found in 66% of roots.

For interpretation of values, the methodology of Landis and Koch was used in Table 2 (11), so that the comparison between sectioning and CBCT in Weine's classification showed very good agreement (kappa 0.74), like the classification of isthmuses at 3 mm (kappa 0.73).

## Discussion

The use of CBCT images is an important clinical tool in diagnosis and endodontic treatment (3). This test allows evaluating periapical lesions, internal and external resorption, verifying the morphology of the root canal, evaluating fractures, performing pre-surgical planning, and also verifying relationship with other important anatomical structures. The ability to reduce or eliminate overlapping of adjacent structures makes CBCT a superior technique compared to conventional periapical radiographs (2,11-16).

The results of this study demonstrate a high incidence of MB2 canals in permanent first molars. In the analysis of CBCT images, MB2 canals were found in 92% of roots and in the cross-sectioning technique, MB2 canals were found in 81% of roots. The various percentages of MB2 canals reported in literature may be explained by the different methodologies used for their detection, as well as the evaluated different ethnical groups and ages (4,5,7,17-19).

The distribution of canal configuration types reported in this study was compared to the classification suggested by Weine et al. (10). In the present work using the cross-sectioning technique, out of the 100 examined roots, 20% were classified as type I according to the Weine's classification, 59% as type II, 20% as type III, and 1% as type IV. By combining the results of type I and II classifications, it was observed that 79% of roots of this study exhibited a single apical foramen. This result is similar to the result

Table 2. Statistics by Cohen's Kappa test of diagnostic agreement between CBCT and cross-sectioning evaluations

Region	Kappa	p-value
Root canal	0.74	0.001
Isthmus at 3 mm	0.73	0.001
Isthmus at 6 mm	0.59	0.001

obtained by Weine et al. (10), who found 86% of roots with a single foramen.

If the single canal in cases of type I and one of the two canals in cases of type II were endodontically treated and properly prepared and filled, the chance of success would be great. In cases of type II, the unfilled canal, regardless of any retained tissue or debris, would be sealed from apical and oral tissues. In cases of type III, if only the largest canal is prepared and obturated, two situations may occur: if the tissue of the unfilled canal is vital and inflamed as a result of any pre-endodontic treatment, pain can persist after the completion of endodontic treatment; if the tissue of the unfilled canal is necrotic, the development of a periapical space may occur or an existing initial injury may perpetuate (10).

In the tomographic analysis in this study, 8% of the samples were classified as type I according to Weine's classification, 56% as type II, and 36% as type III. The results found in Type III is close to the results of Somma et al. (20), who found 2 mesiobuccal canals with independent foramina in 42% of the samples with MB2 canal. In the retrospective study by Guo et al. (21), where the number of roots and the root morphology of 317 cases of first molars were bilaterally assessed, the occurrence of bilateral MB2 canal in maxillary first molars was 65.6%, with statistical difference between groups. According to the classification of Hsu and Kim (9), the highest prevalence was type IV (41.9%), type I (28.3%) and type II canals (26.3%).

Since it is difficult to determine the canal configuration, it is suggested that the floor of the pulp chamber be thoroughly explored, as there is a combination of factors responsible for difficulties found in locating the MB2 canal. Generally, the MB2 canal is the smallest one and undergoes pulpal irritation due to mesial caries. This means that before endodontic treatment, the area most adjacent to this canal experiences the greatest chronic irritation due to caries, deep restorations, infiltrations and so on before irreversible pulpitis. These irritants can stimulate the formation of reactionary dentin or other calcifications that can make the location of the canal difficult (22).

Another factor that makes difficult the determination of the number of canals in the mesiobuccal root is the presence of an isthmus between canals (18). The recognition of isthmuses and accessory canals is a factor that may improve the success rate of the endodontic treatment, as these anatomical structures may act as reservoirs of bacteria and necrotic pulp tissues (7).

The incidence of isthmuses in mesiobuccal roots of maxillary first molars found in this study is consistent with other studies in literature. In the investigation of isthmuses, it was observed that in CBCT, the incidence of isthmuses was greater than in the cross section evaluation. The

predominance of isthmuses at 3 mm from the apex in the CBCT analysis was 36%, and of 66% at 6 mm from the apex. In the cross section analysis, the incidence of isthmuses was 21% at 3 mm from the apex and 54% at 6 mm. Hsu and Kim (9) reported that the incidence of isthmuses may vary from 5 to 53%, higher at 3-5 mm from the apex. Jung et al. (7) found a high incidence of isthmuses at the apical level of 2-5 mm and Degerness et al. (23) observed higher prevalence of isthmuses at the apical level of 3-12 mm. The study of Pécora et al. (24) detected root isthmuses in maxillary and mandibular molars and evaluated their frequencies using map-reading dynamics in CBCT images. The frequency of isthmuses was high in both methods and tooth groups. The authors concluded that the map-reading dynamics in CBCT images is precise for isthmus location.

The recognition and treatment of isthmuses may reduce the failure rate of the endodontic treatment in the mesiobuccal root of maxillary first molars (8). However, in case of periradicular surgery of the mesiobuccal root, Degerness et al. (23) and Von Arx (25), suggest that the section be made to a minimum level to enable greater thickness of the canal wall and access to isthmus areas for proper sealing.

In the present study, there was a positive correlation between CBCT and clinical diagnoses of the cross sectioning technique, which showed good agreement according to Weine's classification ( $\kappa=0.74$ ) and for the classification of isthmuses at 3 mm from the apex ( $\kappa=0.73$ ).

According to the results of this study, it was concluded that compared with CBCT, the cross-sectioning technique showed better results in the detection of the internal morphology of root canals. The incidence of MB2 canals was higher when compared with *in vivo* clinical findings reported in literature. The prevalence of different conformations of root canals configuration and presence of isthmuses are high in the mesial roots of maxillary first molars. CBCT showed excellent concordance in the assessment of the internal morphology of mesiobuccal roots of maxillary first molars and may be clinically applied.

## Resumo

O objetivo do presente estudo foi avaliar a raiz méso-vestibular de primeiros molares superiores, de acordo com a configuração do canal radicular e com a prevalência e localização de istmos a 3 e a 6 mm do ápice, comparando a análise realizada em tomografia computadorizada de feixe cônico (TCFC) com a técnica de seccionamento transversal por terços. Foram obtidas imagens tomográficas das raízes méso-vestibulares de 100 primeiros molares superiores, e em seguida, as raízes foram seccionadas em dois segmentos, iniciando nos 3 mm a partir do ápice. Os dados foram analisados de acordo com a classificação de Weine para configuração de canais radiculares, e de acordo com a classificação de Hsu e Kim para avaliação dos istmos. Na análise das imagens das TCFCs, 8 canais radiculares foram classificados como tipo I, 57 como tipo II, e 35 como tipo III. Na técnica de seccionamento transversal, 19 canais

radiculares foram classificados como tipo I, 60 como tipo II, 20 como tipo III, e 1 como tipo IV. Na avaliação dos istmos, houve predominância do tipo I tanto na TCFC quanto na técnica de seccionamento transversal a 3 mm do ápice. Entretanto, a 6 mm do ápice, a classificação dos istmos foi predominantemente tipo V e II, na avaliação em TCFC e na técnica de seccionamento transversal, respectivamente. A técnica de seccionamento transversal demonstrou melhores resultados na detecção da morfologia interna dos canais radiculares avaliados do que a TCFC.

## Acknowledgements

The authors deny any conflicts of interest related to this study.

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Received February 22, 2015

Accepted July 2015