PREVALENCE AND ANATOMICAL PARTICULARITIES OF THE SECOND MESIOBUCCAL CANAL OF THE PERMANENT UPPER FIRST MOLAR IN THE ROMANIAN POPULATION IN A CLINICAL ENVIRONMENT USING CONE BEAM COMPUTED TOMOGRAPHIC IMAGING- IN VIVO STUDY

Cezar Tiberiu Diaconu[1,†], Anca Elena Diaconu[1], Mihaela Jana Tuculina[1,*], Oana Andreea Diaconu[1,†], Ruxandra Voinea-Georgescu[2, †], Maria Cristina Munteanu [3,†], Lelia Mihaela Gheorghiță[1,†], Cristian Niky Cumpătă [2,†], Bogdan Dimitriu [4], Mihaela Raescu[2, †], Mircea Gheorghiță [3]

[1] Faculty of Dental Medicine, University of Medicine and Pharmacy of Craiova, Department of Endodontics, Craiova, Romania

[2] Faculty of Dental Medicine, University Titu Maiorescu of Bucharest, 67A Gheorghe Petrascu Str., 031593, Bucharest, Romania

[3] Faculty of Dental Medicine, University of Medicine and Pharmacy of Craiova, Department of Oral and Maxillofacial Surgery, Craiova, Romania

[4] Department of Endodontics, Faculty of Dentistry, University of Medicine and Pharmacy Carol Davila Bucharest, 050474, Bucharest, Romania;

*Corresponding author: Mihaela Jana Tuculina *e-mail:* mtuculina@yahoo.com
Bogdan Dimitriu e-mail: bogdan.dimitriu@umcfcd.ro

† These authors contributed equally to this work.

Abstract

One of the most common causes of endodontic treatment failure is inadequate diagnosis and treatment planning of the treated tooth, including lack of comprehensive knowledge about the morphological characteristics and their frequent variations of the entire root canal system. Therefore, a successful root canal treatment depends on a clinician's ability to locate, clean, shape, and fill the entire canal system in all dimensions. The permanent upper first molar (MFM) is the earliest permanent tooth that appears in the oral cavity and that makes it vulnerable to caries and further to the need of endodontic treatment.Permanent maxillary first molars (MFM) generally have three roots with additional canal located in the mesiobuccal root (MB) which are called first mesiobuccal (MB1) and second mesiobuccal (MB2) and loops, intercanal connections, auxiliary canals, and apical ramifications are all common anatomical features. In maxillary molars, a conventional intraoral periapical radiograph provides a 2D view of the root canal system (RCS); as a result, the prevalence of undetected MB2 canal is high; the need for a 3D view of the RCS can be satisfactorily fulfilled by cone-beam CT (CBCT). The prevalence of MB2 has been assessed in several in vitro and in vivo studies, presenting variations according to the methodology applied, along with the population of interest. As a novelty this study aims to analyze the MB2 canal prevalence, anatomy and working length in MFM in the Romanian population using CBCT imaging and clinical notes. In addition, the data obtained will contribute to the currently available evidence in the literature from other parts of the world as well as increase the general dental practitioners (GDP) awareness about the anatomical complexities and variations of the permanent upper first molar. In this retrospective study, CBCT images and clinical notes of 289 patients with ages between 14 and 78 years old presenting 336 upper first molar pathology were reviewed in this study, which was conducted at the Endodontology Department of the Faculty of Dentistry, University of Medicine and Pharmacy Craiova. According to this retrospective study, the romanian people have a high prevalence of the MB2 canal in permanent maxillary first molar regardless of gender. The overall prevalence of the MB2 canal was 75%, with a type II morphology according to Vertucci classification in 69% of cases and an average length of 14.7mm for type II respectively 18.3 mm for type IV canal type.

KEY WORDS: maxillary first molar, second mesiobuccal canal, prevalence, average length, romanian population.

INTRODUCTION

Identification and effective negotiation of all canals are important determinants for the success of any root canal treatment.(1)

The permanent upper first molar (MFM) is the earliest permanent tooth that appears in the oral cavity and that makes it vulnerable to caries and further to the need of endodontic treatment, as such the majority of the endodontic failures were noted in maxillary molars (44.4%), furthermore, the endodontic treatment performed by the general dental practitioners (GDPs) showed the most failure rate (78.8%) (2)

Permanent maxillary first molars (MFM) generally have three roots with additional canal located in the mesiobuccal root (MB) (3). The MB root of MFM is one of the most complex root canal systems (4) and one of the most frequently studied roots both in vitro and in vivo (5).

In the literature, MB root of the MFM has generated more research and clinical investigation than any other root. (6)

Most commonly the MB root has complex anatomy with two main root canals which are called first mesiobuccal (MB1) and second mesiobuccal (MB2) and loops, intercanal connections, auxiliary canals, and apical ramifications are all common anatomical features. (7)

In maxillary molars, a conventional intraoral periapical radiograph provides a 2D view of the root canal system (RCS); as a result, the prevalence of undetected MB2 canal is high; the need for a 3D view of the RCS can be satisfactorily fulfilled by cone-beam CT (CBCT). (8)

Its prevalence has been assessed in several in vitro and in vivo studies, presenting variations according to the methodology applied, along with the population of interest. The worldwide prevalence of MB2 using CBCT was found to be 73.8%, with a range from 48% to 97.6%. Several studies have presented a broad variety of incidences of such canals, ranging from 14% to 94%. (9) For example, in Russia the prevalence of MB2 was found was found to be 59.8% (10), in Poland 59.5% (11) in Japan 88.2% (12) and in Portugal 71% (13). In Europe previous investigations found a higher prevalence rate of MB2 in the Spanish population, 86.2%. (14). Due to the complex anatomical variations of the MB root it is possible that the MB2 canal will be missed in normal clinical practice, especially if no magnification or special illumination equipment is used, leading to failure in maxillary molar root canal treatment.

Anatomical complexities and variations of the RCS present a great challenge for clinicians, with a higher possibility of complications, such as ledges, zips, perforations and canal transportation during the process of canal shaping (15,16), in addition, the MB2 canal is usually narrow with one or two abrupt curvatures in the coronal middle thirds of the canal

(17,18). Moreover, there is a higher risk of file fracture during the preparation of the curved and tiny MB2 canals due to cyclic fatigue and torsional stress (17, 19). Therefore, studies exploring methods for the safe and effective negotiation and preparation of the MB2 canal are crucial for successful root canal treatment. Accurate working length determination is essential to achieve the optimal cleaning and disinfection of the canal (20).

The generally accepted method of working length determination is the radiographic method but the apical constriction cannot be accurately determined radiographically as such the use of electronic apex locator (EAL) was employed which was a high degree of accuracy (87%) according to various studies (20, 21).

The aim of this in vivo study was to analyze the MB2 canal prevalence, anatomy and working length in MFM in the Romanian population using CBCT imaging and clinical notes. In addition, the data obtained will contribute to the currently available evidence in the literature from other parts of the world.

To the authors knowledge there has been no previous studies published evaluating these aspects in the Romanian population.

MATERIALS AND METHODS

In this retrospective study, CBCT images and clinical notes of 289 patients with ages between 14 and 78 years old presenting 336 upper first molar pathology were reviewed in this study, which was conducted at the Endodontology Department of the Faculty of Dentistry, University of Medicine and Pharmacy Craiova. The data were gathered from a private practice patient pool using the SPS Stoma patient software (Smart Project Solutions, Romania) from January 2021 until January 2023.

The search criteria used included "procedure date"- within the determined time period, "procedure code"- primary endodontic treatment, and "tooth number"- 1.6, 2.6.

The search criteria drew patients randomly. This ensured a process of case selection and data collection free of bias. The 2 year period was a reasonable time period to draw sufficient data from and ensured similar endodontic visualization methods and techniques over its course. The data collected was reviewed by 4 endodontists from the Endodontology Department until a consensus was reached. After reviewing all the clinical notes, the intraoperative pictures and the CBCT scans, due to our exclusion criteria only 245 patients presenting 271 upper first molar pathology were included in this study. The exclusion criteria where as follows;

- Missing or insufficient patient data including pre operative and post operative CBCT images and clinical notes
- Teeth with open apices, root resorption, or calcification were excluded from the study

Pre (Fig.1) and post (Fig.2) operative tomographic examination imaging were

acquired using the 8100 3D CBCT equipment (Carestream Health, New York, USA), as part of the patient's dental examination, diagnosis, and endodontic treatment planning. The image capturing parameters were set at 90 kV, with exposure time of 12 seconds at 5.0 mA current with a 5 X 5 field of view. The CBCT imaging was performed following the manufacturer recommendations and the as low as reasonably practicable (ALARP) protocol.

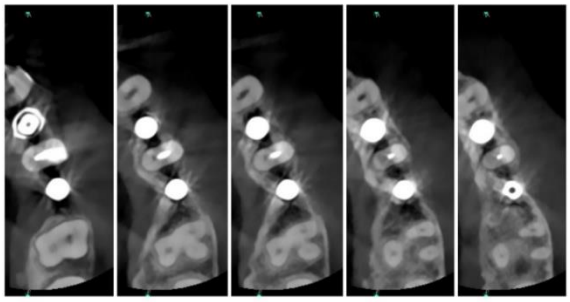

Figure1. Consecutive CBCT slices – axial view from left to right coronal to apical.

Figure 2. Post operative CB-CT imaging-sag-ittal view.

The endodontic treatments were performed according to the modern standard of endodontic treatment using rubber dam isolation and with the aid of a dental operating microscope (DOM) by one of two endodontists with more than 15 years clinical experience. After the endodontic treatment was performed post operative detailed clinical records were taken, including photographic evidence of the presence or absence of MB2 canal. (Fig 3)

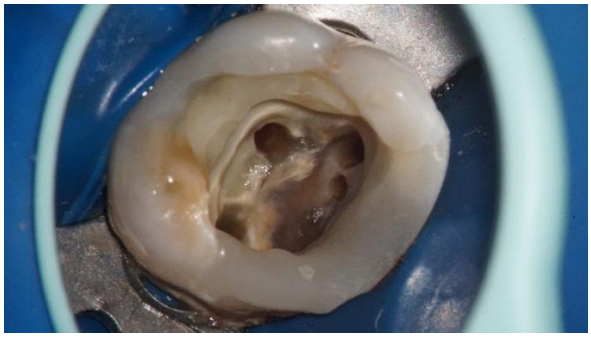

Figure 3. Photographic evidence of MB2 presence.

After reviewing the patients clinical notes and the intraoperative pictures as made by the endodontists after they performed the endodontic treatment the examinators reviewed the pre operative and post operative CBCT scans by scrolling along the axial and sagital sections using the CBCT machine software programme (Carestream Health, New York, USA) to evaluate for the following criteria; frequency of additional canals (MB2) in the mesiobuccal root type of canal according to Vertucci classification (22) (Fig. 4 & Fig. 5)

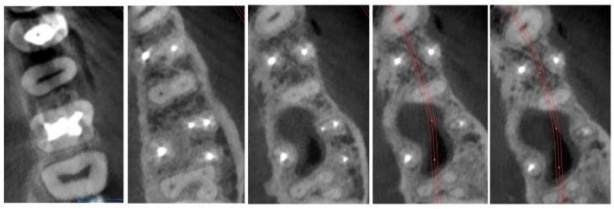

Figure 4. Consecutive post operative CB-CT imaging-axial view, confirming 2 independent canals.

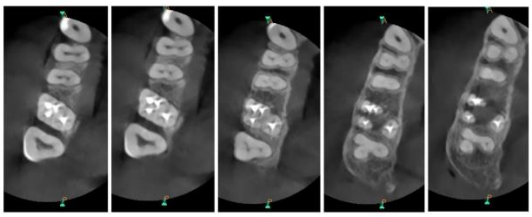

Figure 5. Consecutive post operative CB-CT imaging-axial view, confirming 2 confluent canals.

- gender distribution
- average lenght of MB2

The working length was determined for each canal of every tooth by EAL (Raypex 6 – VDW GMBH, Munich, Germany) intraoperative by using staineless steel K-files of the appropiate dimensions. After the procedure was completed a cb ct scan was done to verify the degree of accuracy of the EAL determination of working length.

After reviewing all the clinical notes, the intraoperative pictures and the CBCT scans, due to our exclusion criteria only 176 MFM presenting MB2 canals were used for the average lenght determination of MB2. The rest of the 27 MFM teeth with MB2 present from the total of 203 teeth with MB2 present where not included for the average lenght determination due to short root canal filling or overfilling.

- age of patient

The cases where divided in 7 groups according to the age of the patients as follows.

Group 1 - age between 14 - 19

Group 2 - age between 20 - 29

Group 3 - age between 30 – 39

Group 4 - age between 40 - 49

Group 5 - age between 50 - 59

Group 6 - age between 60 - 69

Group 7- age between 70 – 78

Statistical Analysis

Statistical analysis was performed using Microsoft Excel (Microsoft Corp., Redmond, WA, USA), together with XLSTAT add-on for MS Excel (Addinsoft SARL, Paris, France). The collected data were analyzed, and the number of canals present in the mesio buccal root and the configurations of these canals were documented as frequencies and percentages. Chi-square test was applied to evaluate the association of root canal morphology of maxillary first molars with respect to gender and age of patient. p-value < 0.05 was considered as statistically significant.

RESULTS

1. Overall MB2 prevalence

Of the 245 patients (156 men and 89 women) included in this retrospective study, based on clinical records and CB CT imaging 271 permanent upper first molar teeth were examined (174 in men and 97 in women

pacients). The age range of the individuals was 14–78 years. The MB2 canal was found in 203 teeth and as such the total incidence of MB2 canals was found to be 75 % as seen in (Tab. I).

Total teeth (%)	Teeth with MB2 present (%)	Teeth with MB2 absent (%)
271 (100%)	203 (75%)	68 (25%)

Table I. The overall prevalence of MB2 în permanent upper first molars.

2. Classification and type of canal according to Vertucci.

The most common canal type in the MB root of the MFM according to Vertucci classification (22) was type II, in 69% of the cases there where 2 canals found that where joining towards the apex. Two independent canals where found in 31% of the cases as shown in (Tab.II).

MB2 present (%)	MB2 confluent – Vertucci type II (%)	MB2 independent – Vertucci type IV (%)
203 (100%)	141 (69%)	62 (31%)

Table II. The distribution of the number of MB2 canals in permanent upper first molars by Vertucci classification.

3. MB2 prevalence by gender

These MB2 canals were found in 126 males and 77 females, with a prevalence of 72% for male patients, respectivly 79 % for female patients. Analyzing the difference in prevalence for the MB2 canal in MFM between men and women, we found that there is not a statistically significant difference between female patients (79.38%) and male patients (72.41%), Chi square p-value being p=0.205>0.05, as seen in (Tab.III)

Gender	MB2 present (%)	MB2 absent (%)	Total (%)
Female	77 (79.38%)	20 (20.62%)	97 (100.00%)
Male	126 (72.41%)	48 (27.59%)	174 (100.00%)
Total	203 (74.91%)	68 (25.09%)	271 (100.00%)

Table III. The distribution of the number of MB2 canals in permanent upper first molars by gender.

4. Average length of MB2

After reviewing the patients clinical notes as made by the endodontists after they performed the endodontic treatment the examinators noted the lenght of MB2 canal and an excel was made where the mean average was found to be 14.7 mm in the cases where MB2 was confluent with MB1, respectively 18.3 mm for independent MB2 canals as seen in (Tab. IV).

Table IV. The mean average lenght in mm of MB2 canal in permanent upper first molars.

Total MB2 present	MB2 confluent (mean average length in mm)	MB2 independent (mean average length in mm)
176	122 (14,7)	54 (18,3)

Furthermore, after the statistical analysis was performed there was no statistically significant difference found (p Chi square=0.411>0.05) between the mean average lenght in mm by gender distribution as seen in (Tab.V)

Gender	MB2 confluent (mean average length in mm)	MB2 independent (mean average length in mm)
Female	44 (14)	23 (17)
Male	78 (15,4)	31 (19,6)

Table V. The mean average lenght in mm of

MB2 canal in permanent upper first molars according to gender.

5. Age distribution.

The prevalence of MB2 in MFM in each age group was 88%, 84%, 75%, 63%, 58%, 43% and 25% respectively, as seen in (Tab. VI). Analyzing the difference in prevalence for MB2 among age groups, we found that there is a significant difference, as the age progressed, the prevalence of MB2 was decreased.

Age group	MB2 present (%)	MB2 absent (%)	Total (%)
1	57 (88%)	8 (12%)	65 (24%)
2	61 (84%)	12 (16%)	73 (27%)
3	44 (75%)	15 (25%)	59 (22%)
4	20 (63%)	12 (37%)	32 (12%)
5	14 (58%)	10 (42%)	24 (9%)
6	6 (43%)	8 (57%)	14 (5%)
7	1 (25%)	3 (75%)	4 (1%)
Total	203 (74.91%)	68 (25.09%)	271 (100.00%)

Table VI. The prevalence of MB2 canals in permanent upper first molars by age groups.

We can observ a high prevalence of MB2 canal in patients below age 50 (88%, 84%, 75%, 63%) then in patients above age 50 (58%, 43% and 25%) as such the patients were then divided into two age groups, <50 and ≥50, and analyzed. We found the that patients below age 50 have a MB2 prevalence of 79% with a significant statistical difference from the patients above age 50 which present a prevalence of 50% as seen in (Tab. VII). p Chi square=0.000051<0.001

Age group	MB2 present (%)	MB2 absent (%)	Total (%)
<50	182 (79.47%)	47 (20.52%)	229 (100.00%)
≥50	21 (50%)	21 (50%)	42 (100.00%)
Total	203 (74.91%)	68 (25.09%)	271 (100.00%)

Table VII. The prevalence of MB2 canals in permanent upper first molars by age (<50 and ≥50).

DISCUSSION

Professionals' negligence of anatomical root variations has been contributed to the high prevalence of missed canals, leading to failures in endodontic treatment. Their association with periapical lesion occurrence emphasizes the importance of correct detection and instrumentation of these canals. (23)

The root presenting with the highest percentage of missed canals (62.8%) was the MB root of the MFM being associated with periapical lesions in 75.2% of cases. Maxillary molar mesiobuccal roots presenting with a missed canal were 3.1 times more likely to be associated with periapical pathology than maxillary molars with all canals identified and treated. (24)

Although, in recent years atempts were made to employ artificial intelligence (AI) in the interpretation of CB-CT in an effort to improve the detection of the MB2, it was concluded that the current AI algorithm has the potential to identify obturated and unobturated canals in endodontically treated teeth,but the AI algorithm is still somewhat affected by metallic artifacts, variations in canal calcifications, and the applied configuration. Thus, further development is needed to improve the algorithm. (25) Another usefull tool when facing complex RCS could be the Print and Try technique (26) which could represent a useful method to simulate the clinical treatment that will be carried out subsequently.

Aung et al. stated in there review of the current literature that the summary estimates of CBCT for the detection of the MB2 canal of the permanent maxillary molars has a 96.6% sensitivity rate.(27) Despite the fact that CB-CT scans do not offer 100% precision it is still the gold standard in detecting MB2 as mentioned by the American Associatin of Endodontists (8), however clinicians should keep in mind that the CB-CT accuracy can vary in different types of teeth(27), as could the prevalence of MB2 canal across different populations, as such, it is of the upmost importance for the clinicians to have a better understanding of the anatomical variations present in different populations groups.

A recent systematic review and meta-analysis illustrated that the prevalence of the MB2 canal in MFM was looked at in 22 investigations (41 populations) with a pooled incidence of 69.6% (64.5%-74.8%) (28)

Several studies found that the prevalence of the MB2 canal in MFM using CBCT ranges between 19.65 and 89.5%, depending on the ethnic groups. In Southern Asia, the highest incidence was found in the Thai population 63.6% (29). In an American study, the prevalence of MB2 in initial treatment was

61.9% (30) Furthermore, the prevalence of MB2 ranged between 44.0 and 88.5% in the Brazilian population. (31, 32, 33)

In accordance with our study which found an overall prevalence of 75% of the MB2 canal in the permanent first upper molars, other investigations in Europe have found MB2 prevalence of 86.2%, 71.3% and 59.5% in Spanish (14), Portuguese (34), and Polish populations(11). Contradictory to Alhujhuj et al.(35) which stated in his recent study that the majority of maxillary and mandibular first molars had three roots and three canals with Type-I Vertucci's classification, we found that in our study the most common canal type in the MB root of the MFM according to Vertucci classification (22) was type II, in 69% of the cases there where 2 canals found that where joining towards the apex.

Regarding the association between gender and the occurrence of the MB2 canal in maxillary molars the present study does not support the findings of Martins et al. (28) which states that there are greater odds of having the MB2 canal in males compared to females ($p<0.05$). In accordance to what was reported by Betancourt et al. (36) and Zheng et al.(37), our findings suggested that there is not a statistically significant difference regarding the gender correlation and the prevalence of MB2 canal in between female patients (79.38%) and male patients (72.41%), Chi square p-value being $p=0.205>0.05$.

Regarding the effect of age on MB2 prevalence, the present study found that there was a statistically significant difference in the incidence of MB2 between different age groups as such this study is in accordance with Xu et al. (38) which stated that the incidence in patients below the age of 50 is significantly different from that in patients aged 50 and above. Contradictory Habib et al. (39) stated that there is no relationship between age and prevalence of MB2 canals. It is speculated that physiological changes associated with age, such as pulp cavity calcification and deposition of secondary dentin (31), may affect the detection of MB2. Whether the incidence is related to other factors, such as medication history, occlusal relationship, chewing habits, and the dietary preferences of patients in different age groups, is worthy of further in-depth study.

Regarding the average length determination of the MB2 canals it is well known that there are intergender, intra-race and inter-race variations which may depend on an existence of a strong genetic influence on tooth dimensions. At the same time, environmental and dietary changes could also affect tooth morphology and dimensions (40) , as such the average length of MB2 canals can vary from one population to another. Karobari in his 2022 study concluded that there are wide disparities concerning root and canal morphology in

permanent dentition, which could perhaps derive from the geographical area studied (41). Within the limitations of our study we determined a mean average length of 18.3 mm for type IV canal variation (21) and 14.7 mm for type II canal.

Regarding the limitations of the study, it attempted to analyze the MB2 prevalence in the south west part of Romania, taking into consideration that the patients come from various locations around the city of Craiova, Romania. This study doesn't reflect the entire romanian population, as such more accurate and reliable data may be generated by increasing the sample size and collecting it from different centers accros the country, leading to a stronger conclusion about the common morphological features and anatomical variations of MFM in the romanian population.

CONCLUSIONS

This study evaluated all of the obtainable CBCT scans of MFM that meet the inclusion criteria. To our knowledge, this is the first retrospective study with a cross-section design that has addressed the topic of MB2 prevalence, anatomical variations and average length among Romanian population in-depth. The study included 271 CBCT images taken between 2021 and 2023. The CBCT scans were obtained from one private practice, therefore, possible biases such as variances in exposure duration and setting were avoided.

According to this retrospective study, the romanian people have a high prevalence of the MB2 canal in permanent maxillary first molar regardless of gender. The overall prevalence of the MB2 canal was 75%, with a type II morphology according to Vertucci classification in 69% of cases and an average length of 14.7mm for type II respectively 18.3 mm for type IV canal type. Based on the results of this study, it's recommended to consider CBCT as an additional diagnostic method before starting root canal treatment of maxillary molars to obtain optimal results and moreover knowing beforehand about this anatomic variance aids a clinician in locating and treating all canals ensuring as such an optimal long term outcome of the root canal treatment.

Institutional Review Board Statement: The study was approved by the Ethics Committee of the University of Medicine and Pharmacy of Craiova (approval date no. 191/18.12.2020).
Informed Consent Statement: Not applicable.
Data Availability Statement: The authors declare that the data from this research are available from the corresponding authors upon reasonable request.
Conflicts of Interest: The authors declare no conflict of interest.
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