Original Article

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The relation between first and second mesiobuccal root canals of permanent maxillary first molars by using CBCT imaging in a Thai Population

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Objective: This study aimed to investigate the prevalence and relationship between first and second mesiobuccal (MB1 and MB2) root canals of permanent maxillary first molars within a Thai population using cone-beam computed tomography.

Materials and Methods: Two hundred twenty-six Mesiobuccal (MB) roots were scanned using CBCT (3D Accuitomo CBCT machine, J Morita Corp.). The Three-dimensional images were subsequently analyzed to confirm the presence of a mesiobuccal 2 (MB2) orifice. Once the MB2 canal was identified, the distance between the main canals and the MB2 orifice was measured. Measurements included the relationship between the first mesiobuccal canal (MB1) and the palatal (P) canal. A straight line was drawn from the centers of each Canal (MB2-MB1 and MB1/P). The MB1 and P line was connected to the center of MB2 using a perpendicular line. The distance was calculated and documented. The data were analyzed using descriptive statistics; and the relationship between gender, side of the mouth, and age of the patients was investigated in this study, with $p<0.05$ considered statistically significant.

Results: The prevalence of MB2 in the study samples was 56.6%. The average distance between MB2 and MB1 canal orifice was 2.29 ±0.39 mm. The distance from the MB2 orifice measured perpendicular to an imaginary line between MB1 and P orifice was 1.12 ±0.29 mm. The inter-orifice distance between MB1 and P canal was 6.77 ±0.76 mm. There was no correlation observed between gender, side, and age or distance of the MB2.

Conclusion: MB2 was prevalent in 56.6 percentage of the study samples. Moreover, there were no significant differences in tooth side and age groups, the MB2 was located clinically approximately 2 mm mesiopalatally to MB1 and approximately 1 mm mesially to an imaginary line from MB1 to palatal canal orifices. Notably, the male group frequently exhibited a longer relative distance than the female group.

Keywords: cone-beam computed tomography, maxillary molars, mesiobuccal root anatomy

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Introduction

One of the greatest challenges in the endodontic field is performing a root canal treatment on the maxillary molars. The root canal morphology of the maxillary molar represents one of the most complex root canal anatomies in human dentition. The ability to locate, debride, and obturate the second mesiobuccal canal (MB2) in the mesiobuccal root (MB root) [1-3] is a crucial factor contributing to the failure of endodontic treatment in maxillary molar. For more effective endodontic therapy, a greater understanding of root canal anatomy and its variations is essential.

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The researchers documented the variation in the MB root of maxillary molars. They reported the prevalence of an MB2 canal in first and second maxillary molars, ranging widely from 57.4% to 77%. Race, age, and gender played key factors in these variations [4, 5]. Previous studies of the prevalence of MB2 canal of maxillary molars in the Thai population reported MB2 ranging from 60% to 65% in the first maxillary molar. These studies used different techniques, including clearing technique and cone beam computed tomography (CBCT) [5, 6]. For the clinician, the identification of MB2 is based on the relationship between the first mesiobuccal canal (MB1). The MB2 orifice is usually located mesial to an imaginary line between the main MB1 and palatal orifices (P) and at about 2-3 mm from the MB1 orifice [7]. Zhuk *et al* [8] found that the distance between MB2 and MB1 orifices was 2.06 mm and 1.03 mm mesial to an imaginary line drawn from MB1 to the palatal canal in the first maxillary molar. This knowledge of the relationship can help clinicians understand root canal anatomy, improving their ability to locate, clean, and obturate all existing canals.

The MB2 canal is located palatally to the MB1 canal. It's important to note that it is not the imaginary line of the palatal canal, which is usually located closer to the mesiopalatal aspect of the MB1. There may be a few exceptions to this, however, in general, the MB2 orifice is about 1 to 3 mm from the MB1 orifice [7, 9]. The pulpal floor has developmental root fusion lines that are darker; these can provide a roadmap for locating the canals, due to the orifices of the root canals being located at the terminus of the root developmental fusion lines [10].

Routine pre-operative periapical radiography is essential but presents some limits in the 3-D structure, including identifying the presence of MB2. Therefore, cone-beam computed tomographic (CBCT) scanning has been used for studying root canal morphology. Clinicians can evaluate teeth in three dimensions when using CBCT imaging in the axial, sagittal, and coronal planes. Furthermore, CBCT imaging provides advanced capabilities: lower effective radiation dosage, shorter exposure time, lower cost than traditional computed tomographic imaging, high resolution, increased accuracy, minimum distortion, and it is non-destructive. We confirmed CBCT to be an efficient method for investigating the MB2 canal in the maxillary molars [5, 11-15].

Numerous studies have researched the prevalence of MB2 and its relationship to MB1 using CBCT [5, 8, 11-15]. However, there is still a lack of study on how CBCT imaging can be used to more accurately determine the relative distance of MB2 to the MB1 orifices in maxillary first permanent molars in a Thai population. The aim of this retrospective study is to determine the location of MB2 in maxillary first permanent molars in relation to the MB1 using CBCT imaging analysis.

Materials and Methods

The Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Institutional Review Board (MU-DT/PY-IRB 2021/DT144) gave ethical approval for this research. We recruited study subjects from the patients requiring CBCT examination as part of their dental diagnosis and treatment. The CBCT scans were performed at the Department of Radiology, Faculty of Dentistry, Mahidol University. From August 2017 to January 2020, 226 patients who met the inclusion criteria were included in this study. The study group

contained 95 men and 131 women between the ages of 18 and 81 years old, and we selected the teeth based on inclusion and exclusion criteria.

Inclusion criteria

- Subjects were included in this study if they were over the age of 18 at the time of the CBCT scan.
- Subjects had a CBCT for the purpose of diagnosis and treatment planning in the maxillary molars area.
- All CBCT images were obtained from a 3D Accuitomo CBCT machine (J Morita Manufacturing Corp, Kyoto, Japan). The scan settings were 80 kVp and 5 mA with a 17.5-second exposure time. A field of view of 60 x 60 mm^2 and a 0.125 x 0.125 mm^2 voxel size will be used.

Exclusion criteria

- The CBCT scan revealed a previously treated tooth
- CBCT imaging presented an obstacle to identifying the MB2 orifice, had an extensive destruction of crown margins, or had an obstruction at the pulpal floor which prevented accurate measurements.
- Any teeth with open apices, calcifications, and resorptions.
- Teeth which presented a lack of a clearly distinctive canal at the level of the pulpal floor or within the range 3 mm lower from the sagittal reference or showed an interfering interpretation of canal due to fin and groove.

Measurement and analyses

The two hundred twenty-six CBCT images were analyzed using the built-in J Morita measurement software and visualized in three distinct planes: axial, sagittal, and coronal as shown in Figure 1. The two-dimensional sectional images were displayed on a monitor using One Volume Viewer software (J Morita Manufacturing Corp). The same methodology was used to orient all CBCT images in this study. Sagittal and coronal

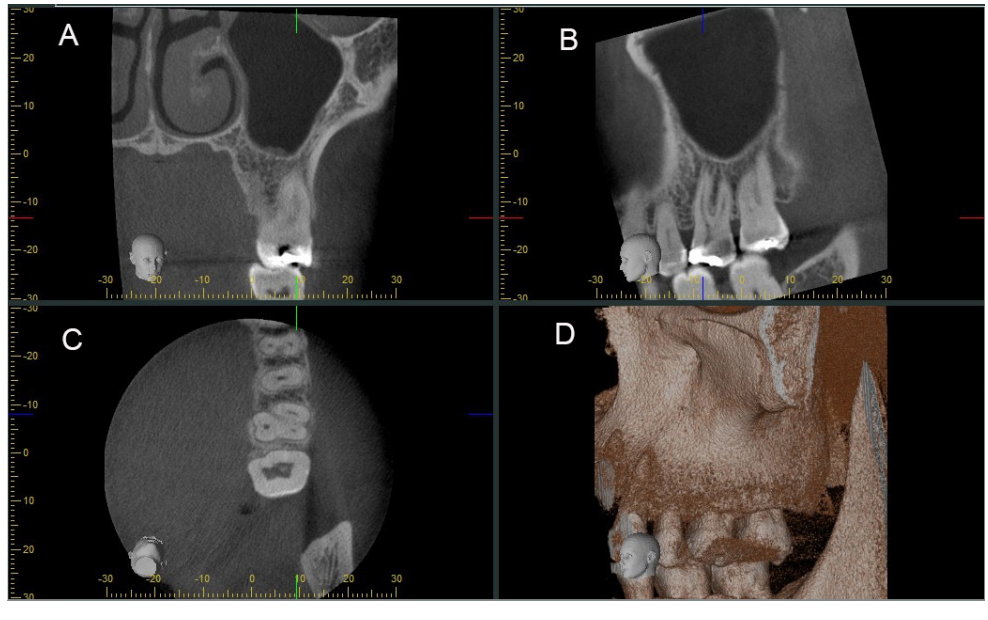

Figure 1 CBCT images of maxillary first molars on the J Morita software's main interface. The coronal view (1A), sagittal view (1B), axial view (1C), and 3-dimensional view (1D). The measuring plane's location is indicated by the red line.

sections were centered and oriented along the long axis of the MB root. Vertucci's classification was used to observe and evaluate the number of root canals from the coronal third to the apical third of the MB root. If the tooth showed the presence of MB2, the distance between the MB2-MB1, MB2-MB1/P, and MB1-P orifice was measured as shown in Figures 2 and 3. The inferior border of the pulpal floor was utilized as the sagittal reference to make the appropriate axial measurement of the MB2 orifice in relation to the MB1 orifice. The MB2 canal was located geometrically to the first mesiobuccal canal (MB1) and the palatal canal (P). Straight lines were placed between the center locations of each canal (MB2-MB1 and MB1/P). A perpendicular line from the center of MB2 was drawn to the MB1/P line. The distance between of MB2 and MB1 (MB2-MB1), a perpendicular line from MB2 to MB1/P (MB2-MB1/P), and MB1 and P orifice were calculated in millimeters. The relationship between the MB2 canal in the MB root along with the gender, age, and tooth side were also determined. For analysis, the age groups were categorized into five groups (18-27, 28-37, 38-47, 48-57, and >57 years old).

The images were evaluated for the existence of MB2 by both a specialist and the assigned researcher. A Kappa test was used to diagnose and assess the reliability of the data. The distance between each canal orifice was measured by one observer, while interobserver reliability was analyzed by the intraclass correlation [15]. All images were measured twice. A second measurement was taken at a minimum of three weeks following the first. The average of the two measurements was then calculated. Data was entered into a Microsoft Excel double-entry spreadsheet table separated by gender, age, tooth side, and distances between the difference points.

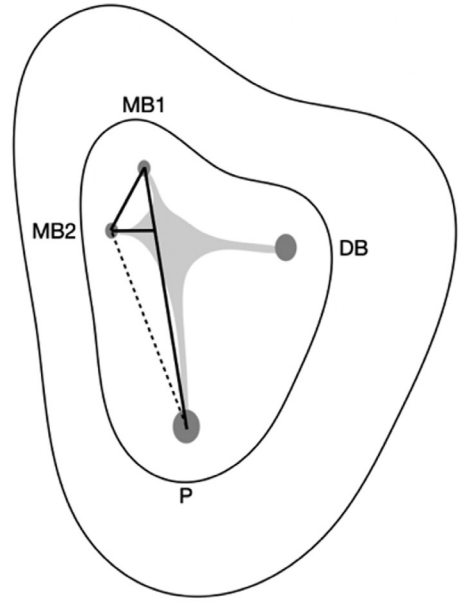

Figure 2 The distances were measured between MB2-MB1, a perpendicular line between MB2-MB1/P, and MB1-Pa orifice

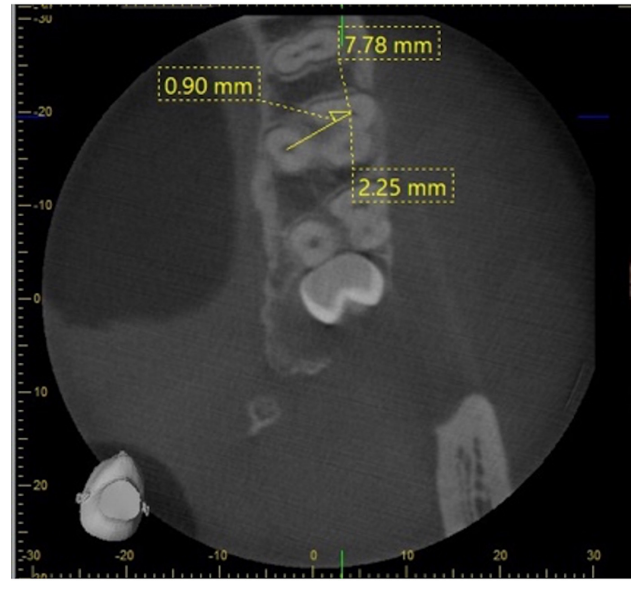

Figure 3 This image is a representative slice of the CBCT image that was analysed, it demonstrates the locations of the MB1, MB2, and P orifices which were localized and measured using the built-in J Morita measurement software.

Statistical analysis

The data were analyzed using descriptive statistics (Mean ± SD. Chi-square was used to determine the differences between prevalence of MB2 and gender, tooth side, and age groups. An independent t-test was used to further analyze the differences in distance between gender and tooth side. The relation of distance among age groups was evaluated by one-way ANOVA. The average distances between points MB2, MB1, and P were measured with 95% and 99% confidence intervals. A significant level of $p<0.05$ was set for statistical reference. For the intra-observer reliability assessment, the intraclass correlation coefficient was employed. Cicchetti provided guidelines for the interpretation of ICC agreement measures as follows; less than 0.40: poor; between 0.40 and 0.59: fair; between 0.60 and 0.74: good; and between 0.75 and 1.00: excellent [16].

Results

A total of 226 maxillary first molars from independent patients were included in this study according to the established inclusion criteria, which included 95 males and 131 females. The age of the patients ranged from 18-81 years old, with an average age of 38.98 ± 16.47 years old.

Intra-examiner and Inter-examiner Reliability

The intra-examiner reliability was 0.9 which is considered excellent according to Cicchetti's criteria. The inter-examiner reliability was 0.71, which is substantial according to the agreement statistics published by Landis & Kosh [17].

Prevalence of MB2 canal and correlation to sex, side, and age

MB2 was prevalent in 56.6% of the study group canals (128/226). The relationships between sex, side, and age were observed. No significant relationship was found between sex and the prevalence of MB2 canals ($p=0.551$) (Table 1). The MB2 canal was found in 58.9% of males and 55.0% of females. The location on the side of the mouth did not show a statistically significant difference ($p=0.823$) (Table 1). The 38 to 47-year age group had the highest incidence of the MB2 canal in the first molars (62.5%), while the 48 to 57-year-old age group had the lowest (41.9%).

Table 1 The Number and Frequency of Second Mesiobuccal Canals in the Mesiobuccal Roots of Maxillary First Molars by Sex and Tooth side

Maxillary first molar (*n=226*)	Sex		*p-Value*	Side		*p-Value*
	Male	Female		Left	Right	
MB2 present, n (%) *(n=128)*	56 (58.9)	72 (55.0)	0.551	66 (55.9)	62 (57.4)	0.823
MB2 absent, n (%) *(n=98)*	39 (41.1)	59 (45.0)		52 (44.1)	46 (42.6)	

There was no significant difference in sex groups and tooth side groups.

Table 2 The Number and Frequency of Second Mesiobuccal Canals in the Mesiobuccal Roots of Maxillary First Molars by Age

Age (years)		n (%)					*p-Value*
		18-27	28-37	38-47	48-57	>57	
Maxillary first molar	MB2 present, *(n=128)*	44 (57.1)	26 (57.8)	22 (68.8)	14 (43.8)	22 (55.0)	0.386
	MB2 absent, *(n=128)*	33 (42.9)	19 (32.2)	10 (31.3)	18 (56.3)	18 (45.0)	

There was no significant difference between age groups.

However, there was no statistically significant difference in the frequency of the MB2 canal in maxillary first molars between age groups (*p=0.386*) (Table 2).

Location of MB2 orifice and the relation to MB1 and P orifice in maxillary first molars

For the 128 (one hundred twenty-eight) CBCT images, the MB2, MB1, and P orifices were located at the center of the canals. The distance was measured as part of the method. The average distance between MB2 and MB1 canal orifice was 2.29 ± 0.39 mm. The average distance from the MB2 orifice perpendicular to an imaginary line between MB1 and P orifice was 1.12 ± 0.29 mm, and the inter-orifice distance between MB1 and P canal was 6.77 ± 0.76 mm

Relation of MB2 orifice to MB1 and P orifice by Genders, Tooth side, and Age

This study analyzed the difference in distance between MB1 and MB2 for each gender. There was a statistically significant difference in the distance between MB1 and MB2 in male and female teeth (2.41 ± 0.44 mm, 2.19 ± 0.31 mm, respectively) (*p=0.001*, mean difference 0.22 ± 0.64 mm), as well as the shortest measurement between MB2 and the line drawn from MB1 and P canals (1.19 ± 0.31 mm in males and 1.08 ± 0.27 mm in females) (*p=0.031*, mean difference 0.11 ± 0.49 mm). However, the differences in distances from the MB1 to the P canal between the two genders were not statistically significantly different (6.91 ± 0.72 mm in males and 6.65 ± 0.75 mm in females) (*p=0.051*) (Table 3). There was no significant correlation between the distance and tooth side (*p=0.950*) except the distance between MB1 and P (*p=0.027*, mean difference 0.28 ± 0.13 mm) (Table 3). Orifices among age groups showed no statistically significant difference (*p>0.05*) for the location of MB2 measurements (Table 4).

Discussion

Several methodologies were utilized to study root canal morphology including clearing [6, 18], micro-computed tomographic, and CBCT. CBCT imaging is widely used to assess root canal morphology because of its high precision, low distortion, 3D visualization, and non-destructive method. However, this study found that the presence of a post in the crown of adjacent teeth caused scattered radiation rays, which slightly

Table 3 The Measurement of the distance between Root Canal Orifices by Sex and Tooth side

Distance (mm)	Sex		p-Value	Side		p-Value
	Male (n=56)	Female (n=72)		Left (n=62)	Right (n=66)	
MB2-MB1 orifice						
Mean ± SD	2.41 ± 0.44*	2.19 ± 0.31*	0.001	2.29 ± 0.34	2.29 ± 0.43	0.950
MB2-MB1/Pa orifice						
Mean ± SD	1.19 ± 0.31*	1.08 ± 0.27*	0.031	1.12 ± 0.25	1.13 ± 0.33	0.782
MB1-Pa orifice						
Mean ± SD	6.91 ± 0.72	6.66 ± 0.75	0.051	6.91 ± 0.75**	6.62 ± 0.72**	0.027

*Significant difference between sex groups ($p<0.05$)

**Significant difference between tooth side groups ($p<0.05$)

Table 4 The Measurement of the Distance between Root Canal Orifices by Age

Distance (mm)	Age (years)					p-Value
	18-27 (n=44)	28-37 (n=26)	38-47 (n=22)	48-57 (n=14)	>57 (n=22)	
MB2-MB1 orifice						
Mean ± SD	2.28 ± 0.45	2.30 ± 0.26	2.22 ± 0.34	2.26 ± 0.30	2.35 ± 0.42	0.732
MB2-MB1/Pa orifice						
Mean ± SD	1.13 ± 0.31	1.13 ± 0.25	1.08 ± 0.24	1.08 ± 0.25	1.20± 0.31	0.658
MB1-Pa orifice						
Mean ± SD	6.79 ± 0.75	6.82 ± 0.87	6.70 ± 0.61	6.80 ± 0.85	6.70 ± 0.69	0.930

There was no significant difference between age groups.

impaired the ability to accurately visualize the reference plane. Adjusting contrast in the CBCT imaging computer program improved the quality, increasing the ability to locate the existence of MB2 and determine the reference plane. In a previous in vitro study, Matherne *et al* [19] demonstrated that CBCT is superior to conventional radiography in detecting the presence of additional canals, and Blattner *et al* [11] found that CBCT is a more reliable method for detecting the MB2 canal than periapical radiographs. Even though CBCT is useful for endodontics, it also has limitations in detecting root canals when the canal is smaller than the voxel size; in such cases, it cannot detect the presence of the canal [20].

In this study, the inter-examiner reliability was 0.71 which represented good reliability and the intra-examiner reliability was 0.9 which is

considered excellent according to Cicchetti's criteria. Therefore we had the 226 (two hundred twenty-six) CBCT images of Thai maxillary first molars analyzed and revealed that MB2 canals were present 56.6% (128/226) of the time, which was slightly less than the previous studies in the Thai population by Ratanajirasut *et al* (63.6%) [5] and by Alavi *et al* (67.3%) [6]. The use of different research methods (tooth clearing method vs. CBCT) and the amount of sample size, may have resulted in the lower presence of MB2. Nevertheless, the prevalence of the MB2 canal in maxillary first molar in Asian groups such as Burmese, Japanese, Koreans, and Chinese populations in other studies varied from 50.4% to 70%, aligning with the results of our study [12, 21-24].

In addition, the data showed no statistical correlation in the prevalence of MB2 between genders, tooth side, and age. However, other studies indicated males tend to exhibit the prevalence of MB2 in the maxillary first molars [8, 25-27], and were predominantly more likely to manifest MB2. Furthermore, variations in male root canal morphology are usually more distinctive than in female or other teeth. Altunsoy *et al* [28] showed the root and canal morphology of the maxillary and mandibular anterior teeth in a Turkish population by analyzing cone-beam computed tomography (CBCT) images. These images had higher variations of the two canals in males. However, this study showed no difference between males and females for the prevalence of MB2 in the first upper molars [21, 24, 29-31]. Therefore, a controversy still exists. With the exception of the location of the MB2 tooth (side of the mouth), we verified the results of this study directly corresponded with all other previous studies [5, 6, 21, 24, 29-31]. Further confirming that there are no significant differences in the prevalence of MB2 between the right and left maxillary first molars.

Our study did not show a clear prevalence of MB2 between age groups. However, 38-to 47-year-olds possessed the highest prevalence of MB2 (68.8%), while those aged 48-57 presented the lowest prevalence (43.8%). This may be due to a greater presence of secondary dentine deposition located in older teeth. Reparative dentine results in older teeth being exposed to more external stress, such as tooth decay, dental trauma, or restorative operations. This calcification of the canal and the MB2 was more likely to be occluded and undiagnosed, according to Thomas *et al* [32] . However, there was no statistical difference noted between all age groups in this study. Dentists should be aware of these facts while locating an MB2 canal in patients of any age. Moreover, in order to more accurately investigate a correlation between the prevalence of MB2 and a patient's age, a controlled sample size among these age groups is needed for further study.

This study determined that the location of MB2 and its relation to MB1 and palatal canal orifices were located at an average distance of 2.29 ± 0.39 mm between the orifices of the MB2 and MB1 canals. The distance of the MB2 canal orifice was presented mesially to MB1-P at 1.12 ± 0.30 mm, and the distance between MB1 and P canal was 6.77 ± 0.76 mm.

These findings coincided with previous studies of Betancourt *et al* [25] and Zhuk *et al* [8] using the same CBCT technique. Betancourt *et al* found that the average MB1-MB2 inter-orifices distance was 2.68 ± 0.49 mm, 1.25 ± 0.34 mm for MB2 to MB1/P line and for MB1-P it was 7.64 ± 1.04 mm. Whereas, Zhuk's findings indicated the distance between MB1

and MB2 was 2.03 ± 0.55 mm. The shortest measurement between MB2 and MB1/P was 1.03 ± 0.33 mm and the distance between MB1 and P canal was 6.87 ± 1.03 mm. These results were slightly different from the studies of Asian populations by Qiao *et al* [33] who observed a shorter distance in MB2 – MB1, which was only 1.37 ± 0.48 mm and 0.64 ± 0.34 mm for the inter distance between MB2 – MB1/P. This was a slightly shorter distance compared with the findings of Su C. *et al* [27], who documented that the average inter-orifice distance for MB1-MB2 was determined to be only 1.91 ± 0.59 mm and 5.73 ± 0.66 mm for MB1-P.

These discrepancies in distances could be due to the variations of standardized reference plane settings used in the CBCT program. CBCT imaging offers the ability to align the tooth and canals in three separate planes along the long axis, which is not the same as the aforementioned methodologies. However, from the results of all the previous studies when compared to the MB1 orifice, the MB2 orifice always appears in a mesial and palatal direction in the range of 0.6 – 1 mm and 1.9 – 2.6 mm [7-9, 26, 27], respectively.

The variations between males and females in the location of the MB2 orifice were investigated. Both inter-orifices distances of MB1 and MB2 and the shortest distance between MB2 and MB1-P were shown to have statistically significant differences between male and female patients ($p<0.05$). However, the MB1-P distance among the two gender groups was not significantly different, with the $p=0.05$. Therefore, further investigation is needed into these variations. The larger tooth structure of males could be the main factor for the difference in distance, which corresponds with other previous studies [8, 25-27].

That being said, there were no statistical differences between the tooth side and all relative distances, with the exception of the MB1-P inter-orifice distance ($p<0.05$). This result might be coming from a large degree of divergence in palatal root found in two of the samples, which may have caused a deviation in the gathered information of MB1-P distance data. In addition, as with other previous studies, we found these results to be consistent with the tooth being on the left or right side of the mouth not affecting the morphology. Therefore, there were no statistically notable differences between all relative distances as reported above [5, 8, 21, 30].

It has been long thought that there is a direct relation between age and distance of MB2. As we get older, dentine deposition from trauma, decay, or physiologic change in pulp might affect the distance, making it longer than younger people's teeth. However, this study found that there was no discernable relation between distance and age. Although some samples showed the appearance of dentine deposits, this did not change the center of the canals and had a negligible impact on the inter-orifice distance [8, 13]. We hope this finding can be used as a clinical guide for clinicians helping them to locate MB2 canal orifice more precisely, but also to improve the overall outcome of routine endodontic treatment.

Conclusion

In conclusion, the root canal system in the mesiobuccal roots of Thai maxillary first molars is particularly sophisticated. The prevalence of MB2 canals in the sample groups was 56%. In addition, with no differences in tooth side and age groups,

the MB2 was located clinically 2.29 ± 0.39 mm mesiopalatally to MB1 and 1.12 ± 0.29 mm mesially to an imaginary line from MB1 to palatal canal orifices. Notably, the male group frequently exhibited a longer relative distance than the female group.

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no

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no

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