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Original Article

Analysis of Root and Canal Morphology of Maxillary First and Second Molars among Malay Ethnic in the Malaysian Population with the Aid of Cone-Beam Computed Tomography: A Retrospective Study

Nadzirah Abd Rahman[1,2], Mohamad Syahrizal Halim[1,2], Mohd. Fadhli Khamis[2,3], Huwaina Abd Ghani[1,2]

[1]Conservative Dentistry Unit and [3]Forensic Odontology and Oral Biology Unit, School of Dental Sciences, Universiti Sains Malaysia, Health Campus, [2]Hospital Universiti Sains Malaysia, Health Campus, Kubang Kerian, Kelantan, Malaysia

Abstract

Aim: This study aimed to investigate the root and canal morphology of permanent maxillary first and second molars using cone-beam computed tomography (CBCT) imaging. **Materials and Methods:** This study evaluated the CBCT images of 480 maxillary first molars and 536 maxillary second molars from 268 patients who received CBCT scanning for various procedures. The number of roots, prevalence of the second mesiobuccal (MB2) canal in the mesiobuccal root, its association with gender, and the prevalence of bilateral MB2 canals were evaluated. Descriptive statistics was used to evaluate the prevalence, while Chi-square test was used to assess the association between the prevalence of MB2 canal and gender with a significance level set at $P < 0.05$ and $P < 0.001$. **Results:** Majority of maxillary first (97.7%) and second molars (80.0%) were presented with three roots. MB2 canals were found in 59.9% and 35.2% of maxillary first and second molars, respectively. The prevalence of MB2 canals among male patients was significantly higher in both maxillary first ($P < 0.05$) and second molars ($P < 0.001$). Bilateral MB2 canals were seen in 76.2% and 58.3% of maxillary first and second molars, respectively. **Conclusions:** MB2 canal was common among Malay ethnic with the prevalence of approximately 60% and 35% in maxillary first and second molars, respectively. Our findings will increase the knowledge and awareness of dental clinicians to be more vigilant in identifying the MB2 canal to ensure complete cleaning and obturation of all root canals during root canal treatment.

Keywords: Cone-beam computed tomography, Malay, maxillary first molar, maxillary second molar, root and canal morphology

Introduction

Root and canal morphology knowledge determines the success of root canal treatment (RCT). Majority of failures in RCT resulted from missed second mesiobuccal (MB2) canals in maxillary first and second molars.[1-5] Cone-beam computed tomography (CBCT) has been extensively used to study root and canal morphology due to its noninvasiveness, high resolution, and accuracy.[6,7] Due to the lack of standard data, this study aimed to evaluate root canal morphology of maxillary first and second molars among Malay ethnic within the Malaysian population using CBCT imaging with specific objectives of evaluating the number of roots, the prevalence of MB2 canal, its association with gender, and the prevalence of bilateral MB2 canals.

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Materials and Methods

This is a retrospective cross-sectional study utilizing CBCT scans to determine the prevalence of MB2 canals in permanent maxillary first and second molar teeth among patients attending the dental clinic in the School of Dental

Address for correspondence: Dr. Huwaina Abd Ghani, School of Dental Sciences, Universiti Sains Malaysia, Health Campus, 16150 Kubang Kerian, Kelantan, Malaysia.
E-mail: huwaina@usm.my

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Sciences of Universiti Sains Malaysia. Ethics approval was obtained from the Human Research Ethics Committee of Universiti Sains Malaysia, Malaysia, with the reference number of USM/JEPeM/18010034), and the sample size of 260 patients was found to be adequate to estimate the prevalence to an accuracy within 10% (0.1). A total of 2225 CBCT scans (from January 1, 2010, to December 31, 2018) were examined for the inclusion criteria. Two hundred and sixty-eight consecutive cases, representing 137 female and 131 male patients, which met the criteria, were included in this study. The average patient age was 37 years (ranging from 14 to 69 years). The inclusion criteria were defined as follows: Malay ethnic, age: 14–69 years old, fully mature apices, and intact roots. In contrast, the exclusion criteria were defined as follows: the presence of periapical periodontitis, root canal treated tooth, posts or crown restorations, canal calcification, external or internal root resorption, caries that reach the trifurcation area, and low-quality images or interference of artifacts.

The CBCT images were previously obtained using three-dimensional Planmeca Promax (Finland) with the following parameters: 90 kVp, 10 mA, a field of view 80 mm × 80 mm, voxel size 320 µm, and dosage of 1233 DAP (mGy × cm^2). Axial, coronal, and sagittal two-dimensional sections of the chosen images were displayed on a monitor (Dell SE2717H 27-inch Full HD LED-Lit, 1920 × 1080 resolution, Dell Inc., Texas, United States) and were inspected using Romexis 2.9.2 viewer software (Planmeca USA, Inc.). Reformatted images were magnified by 180% and were analyzed with a slice thickness of 0.25 mm for a clear radiographic evaluation of the root canal morphology in the maxillary first and second molars. The number of root canal from the coronal third to the apical third of each root was observed according to the Vertucci's classification with modifications.[7,8] The prevalence of bilateral MB2 canals in the mesiobuccal (MB) roots of maxillary first and second molars was calculated.

The examiners performed intra- and interexaminer calibrations based on the anatomic diagnosis of CBCT images, and the kappa statistic was used to test data reliability. An endodontist and an investigator analyzed 10 randomly selected CBCT images of morphologically diverse maxillary molars. The images were assessed twice by both the examiners, with a 1-week interval between the evaluations. The measure of agreement based on Cohen's kappa for intra- and interexaminer calibrations was almost perfect (1.00) and strong (0.82), respectively.[9] SPSS software (IBM® SPSS® Statistics version 24, Chicago, USA) was used to perform descriptive and statistical analyses. Descriptive data were reported in the form of frequency and percentage. Chi-square test was used to compare the prevalence of MB2 canal in maxillary second molar MB root between the gender and tooth side with a significance level set at $P < 0.05$ and $P < 0.001$.

Results

Number of roots and morphology

The number of roots in each of the 480 maxillary first molars and 536 s molars was determined [Table 1]. The prevalence of three-rooted first molars was 469 (97.7%), and in second molars, it was 429 (80.0%). None of the first molars had four roots, while only 2 (0.4%) of the second molars had four roots, which consisted of three buccal roots and one palatal root. The extra buccal roots had no detectible canal. There was more morphological variation, particularly the fusion of roots, in the second molars than in the first molars. The prevalence of two-rooted first molars was 11 (2.3%). Among these two-rooted first molars, seven teeth were presented with separate buccal and palatal roots, while four teeth were presented with mesial and distal roots. On the other hand, 26 (4.9%) single root and 79 (14.7%) two roots were detected in second molars. Among the second molars with two roots, 60 teeth were presented with separate buccal and palatal roots and another 19 teeth had mesial and distal roots.

Number of canals and morphology

The distribution frequency of canal configurations in the maxillary first and second molars was evaluated [Tables 2-4]. The number and frequency of MB2 canals were presented in the MB roots of three-rooted first and second molars by 59.9% and 35.2%, respectively [Table 2]. The most common canal configuration in the MB roots of three-rooted first and second molars was Type I, followed by Type IV and Type II [Tables 3 and 4]. In the first molar and second molar of distobuccal roots, Type I canal configuration was the most common with only two (1 first and 1 second molar) had Type IV canal configuration. Meanwhile, the

Table 1: Frequency distribution of root number according to the tooth position

Number of root	Maxillary first molars, *n* (%)	Maxillary second molars, *n* (%)
1 root	0	26 (4.9)
2 roots	11 (2.3)	79 (14.7)
B and Pa roots	7 (1.5)	60 (11.2)
M and D roots	4 (0.8)	19 (3.5)
3 roots	469 (97.7)	429 (80.0)
4 roots	0	2 (0.4)
Total	480 (100.0)	536 (100.0)

B – Buccal, Pa – Palatal, M – Mesial, D – Distal

Table 2: The number and frequency of mesiobuccal canal in the mesiobuccal root of three-rooted maxillary first and second molars

Number of teeth	The number of MB canal in the MB root, *n* (%)	
	One	More than one
Maxillary first molars (*n*=469)	188 (40.1)	281 (59.9)
Maxillary second molars (*n*=429)	278 (64.8)	151 (35.2)

MB – Mesiobuccal

palatal (Pa) roots of three-rooted first and second molars were presented with Type I canal configuration (100%).

In the buccal roots of two-rooted first molars, the most common canal configuration was Type I (28.6%), Type II (28.6%), and Type IV (28.6%). The Pa roots of two-rooted first molars had Type I (85.8%) and Type II (14.2%) canal configurations. In two-rooted first molars with mesial and distal roots, the most prevalent canal configuration was Type I (25.0% and 75.0%, respectively). The most common canal configuration in the buccal roots of two-rooted second molars was Type I (51.7%), Type II (30.0%), and followed by Type IV (6.6%). The Pa roots of two-rooted second molars had only type I (100.0%) canal configuration. Two-rooted second molars with mesial and distal roots had Type IV (89.5%) and Type I (100.0%), respectively, as the most prevalent canal configurations. In this study, single-rooted maxillary second molar teeth were more frequently presented with additional Type 3–2 (26.9%) followed with Type I (23.1%).

Association of the second mesiobuccal canal with gender and tooth side

There was an association between male and the prevalence of the MB2 canals in both maxillary first ($P < 0.05$) and second

Table 3: Configuration of root canal systems in maxillary first molars ($n=480$)

Number of teeth	Root	Type of canal configuration, *n* (%)								
		I 1	II 2-1	III 1-2-1	IV 2-2	V 1-2	VI 2-1-2	VII 1-2-1-2	VIII 3-3	Additional 3-2
2 roots (*n*=7)	B	2 (28.6)	2 (28.6)		2 (28.6)					1 (14.2)
	Pa	6 (85.8)			1 (14.2)					
2 roots (*n*=4)	M	1 (25.0)	1 (25.0)	1 (25.0)					1 (25.0)	
	D	3 (75.0)	1 (25.0)							
3 roots (*n*=469)	MB	188 (40.1)	84 (17.9)	32 (6.8)	103 (22.0)	49 (10.4)	8 (1.7)	3 (0.6)	2 (0.5)	
	DB	468 (99.8)				1 (0.2)				
	Pa	469 (100)								

B – Buccal, Pa – Palatal, M – Mesial, D – Distal, MB – Mesiobuccal, DB – Distobuccal

Table 4: Configuration of root canal systems in maxillary second molars ($n=536$)

Number of teeth	Root	Type of canal configuration, *n* (%)									
		I 1	II 2-1	III 1-2-1	IV 2-2	V 1-2	VI 2-1-2	VII 1-2-1-2	VIII 3-3	Additional	
									3-2	2-3	3-1
1 root (*n*=26)		6 (23.1)	3 (11.5)	2 (7.7)		1 (3.9)			3 (11.5)	7 (26.9)	1 (3.9)	3 (11.5)
2 roots (*n*=60)	B	31 (51.7)	18 (30.0)	1 (1.7)	4 (6.6)	3 (5.0)				2 (3.3)	1 (1.7)	
	Pa	60 (100.0)										
2 roots (*n*=19)	M				17 (89.5)					2 (10.5)		
	D	19 (100.0)										
3 roots (*n*=429)	MB	278 (64.8)	39 (9.1)	25 (5.8)	43 (10.0)	37 (8.6)	5 (1.2)			2 (0.5)		
	DB	428 (99.8)				1 (0.2)						
	Pa	429										
4 roots (*n*=2)	MB	(100.0) 2 (100.0)										
	B	-										
	DB	2 (100.0)										
	Pa	2 (100.0)										

B – Buccal, Pa – Palatal, M – Mesial, D – Distal, MB – Mesiobuccal, DB – Distobuccal

Table 5: The number and frequency of the second mesiobuccal canal in the mesiobuccal root of three-rooted maxillary first molars by gender and tooth side

Number of teeth	Sex		Tooth side	
	Male	Female	Right	Left
Maxillary first molars (*n*=469)	245	224	243	226
Frequency of MB2 canals, *n* (%)	160 (65.3)*	121 (54.0)	145 (59.7)	136 (60.3)
Maxillary second molars (*n*=429)	239	190	214	215
Frequency of MB2 canals, *n* (%)	104 (43.5)†	47 (24.7)	76 (35.5)	75 (34.9)

*Significant difference compared with females (P=0.02), †Significant difference compared with females (P=0.00). MB – Mesiobuccal

molars ($P < 0.001$) [Table 5]. Therefore, the null hypothesis was rejected. The prevalence of MB2 canals in the maxillary first molars of male patients was 65.3%, while in female patients, it was only 54.0%. Likewise, the prevalence of MB2 canals in the maxillary second molars of male patients was also higher (43.5%) compared to female patients (24.7%). In contrast, there was no significant difference in the prevalence of MB2 canals between the tooth side in either first or second molars ($P > 0.05$) [Table 5]. The bilateral occurrence of MB2 canals in the MB roots of maxillary first and second molars was presented in 112 (76.2%) and 57 (58.3%) patients, respectively [Table 6].

Discussion

The study of root and canal morphology possesses endodontic and anthropological significance.[10,11] Interestingly, root and canal morphology varies greatly among different populations and even among different individuals from the same population. Furthermore, root and canal morphology is an important factor to consider in RCT because the success rate heavily depends on identification, adequate cleaning, and complete obturation of all root canals. For instance, if two separate canals join together into one canal at a distant length from the apex, the treatment of only one canal may suffice to yield success with a low chance of failure.[12] However, if the canals are joined together near the apex or exit as two separate foramina, the failure rate to debride both the canals will be higher because the remaining microorganisms and organic debris are close to the apical foramen.[13,14] Therefore, every clinician should fully understand the anatomical complexities of the root canal system to provide an effective root canal debridement.

Previous *in vitro* studies of root and canal morphology generally involved extracted teeth using various methods such as magnification with microscope, sectioning, clearing and staining, conventional radiograph, and micro-computed tomography to allow direct observation of the root canal systems although time consuming, tedious, and limited sample size.[14-20] Recently, more studies have been utilizing CBCT as a method to study root and canal morphology.[6,21-31] CBCT imaging is more accurate, effective, and reliable as a diagnostic tool compared to other imaging modalities and conventional methods.[23,32] For clinical settings, the American Association of Endodontics and American Academy of Oral and Maxillofacial Radiology recently came up with a comprehensive guideline regarding the use of CBCT imaging in endodontics for the initial assessment of teeth with suspected additional canals and complex anatomy.[4] However, clinicians should not use CBCT imaging routinely unless indicated because it has higher radiation exposure and more expensive compared to an intraoral radiograph.[2,6]

Table 6: Unilateral and bilateral occurrence of the second mesiobuccal canals in the mesiobuccal roots of three-rooted maxillary first and second molars

Number of patients	Bilateral, *n* (%)	Unilateral, *n* (%)
Maxillary first molars (*n*=147)	112 (76.2)	35 (23.8)
Maxillary second molars (*n*=96)	56 (58.3)	40 (41.7)

Using similar imaging methods, Al-Kadhim *et al.* reported that 98% of maxillary first molars have three separate roots, which is almost identical to our finding (97.7%).[21] Our result is also consistent with a study from our neighboring country, Thailand, which found that 99.8% of first molars and 87.1% of second molars have three roots.[6] However, we found a slight anatomical variation of maxillary first and second molars in Malay ethnic. The presence of two roots was observed in both maxillary first molars (2.3%) and second molars (14.7%). In contrast, Ratanajirasut *et al.* did not find any maxillary first molar with two roots, while it was observed in 9.2% of their second molars.[6] It can be concluded that Malay ethnic showed a higher occurrence of root fusion in both maxillary molars compared to the Thailand population. This difference highlights the influence of ethnic background on maxillary molars root morphology. Maxillary second molars showed a greater variation in root numbers and morphology compared to the first molars. Single-, two-, and four-rooted teeth were found in many previous studies, which are consistent with our findings.[6,15,16,19,26,28,29,31,33]

In our study, the prevalence of MB2 canal in three-rooted maxillary first and second molars was 59.9% and 35.2%, respectively. Our prevalence of MB2 canal in the first molars was slightly higher than Al-Kadhim *et al.*(45.6%).[21] This difference could be due to our inclusion criteria of only Malay ethnic, instead of including Chinese and Indians ethnic. Hence, our finding was descriptive of a single ethnic, instead of the general population. Otherwise, our results are generally consistent with the findings from other studies involving Asian populations, namely Thai, Korean, Chinese, Burmese, Indian, and Japanese [Table 7]. These populations showed a similar prevalence of MB2 canals in the first molars, which was in the range of 46.0%-69.0%.[3,6,14-16,20,26-29,31,33-36] On the other hand, the prevalence of the MB2 canal in the second molars has a lower and wider range than the first molars, which is from 7.0% to 55.0%.[3,6,15,16,26,27,29,31,33,35]

It was found that Type IV is the most common canal configuration, followed by Type II, in the MB roots of maxillary first and second molars. This is consistent with previous studies recorded that Type IV was the most prevalent canal configuration in the first molar MB roots.[3,14,15,16,26,31] In the second molar MB roots, both Type II and Type IV were more prevalent.[3,15,16,26,31] Type IV MB canal in the first molar is quite common among Asian populations, which is contrast to the studies among Caucasians in the United States where Type II canals were more frequently observed.[18]

Our results show an association between gender and the prevalence of the MB2 canal in the MB root of three-rooted maxillary first and second molars. Male patients have a significantly higher prevalence of MB2 canals in both first

Table 7: Literature review comparison of the incidence of the second mesiobuccal canal among the Asian populations

Author	Years	Population	Method	Incidence of MB2 canal (%)	
				Maxillary first molar	Maxillary second molar
Ng *et al*.	2001	Burmese	*In vivo* clearing	68	49
Alavi *et al*.	2002	Thai	*In vivo* clearing	65	55
Park *et al*.	2009	Korean	Micro CT	65.2	
Neekalantan *et al*.	2010	Indian	CBCT	48.2	38
Zheng *et al*.	2010	Chinese	CBCT	52.2	
Zhang *et al*.	2011	Chinese	CBCT	52	22
Yamada M *et al*.	2011	Japanese	Micro-CT	55.6	
Peeters *et al*.	2011	Indonesian	*In vivo* clinical RCT	68.5	
Kim *et al*.	2012	Korean	CBCT	63.6	34.4
Tian *et al*.	2016	Chinese	CBCT	67.8	29.7
Al-Kadhim *et al*.	2017	Malaysian	CBCT	45.6	
Mohan *et al*.	2017	Indian	CBCT	64.1	23
Lin *et al*.	2017	Taiwanese	CBCT	66	7.7
Ratanajirasut *et al*.	2018	Thai	CBCT	63.6	29.4

RCT – Root canal treatment, CBCT – Cone-beam computed tomography, micro-CT – Micro-computed tomography, MB – Mesiobuccal

and second molars than females. However, there have been inconsistent findings on the correlation between gender and prevalence of MB2 canal in maxillary molars in other studies.[4,6,21,26,28,29,31] Therefore, a definite relationship between these two variables has yet to be confirmed and established.

There were a few limitations in our study which could be improved by future studies. Due to the large sample size, our subjects were collected through a convenience sampling method; thus, the prevalence may not represent the whole population of Malay ethnic. Future studies should incorporate a random sampling method for a more accurate prevalence that represents the whole population of interest. Moreover, this was a cross-sectional study in which the data were collected from a population at only one specific point of time, during which different individuals with similar characteristics were compared. A longitudinal study in which a group of subjects are observed over time may have more power than ours, as a longitudinal study can help to establish causal factors, such as age and association with gender. However, a longitudinal study is expensive and time consuming. Furthermore, the patients will receive a higher dose of radiation over the course of the study.

Maxillary first and second molars commonly had three roots; although the second molars were more likely to have variations in the number of roots. MB2 canals were commonly presented as Type IV canal configuration. Male gender was associated with a significantly higher prevalence of MB2 canals in the maxillary first and second molars. Most of the MB2 canals were bilaterally symmetrical. Our findings are beneficial for the clinicians as the high prevalence of the MB2 canal in maxillary molars will justify additional investigations to search for it during access cavity preparation. Therefore, this information helps the clinicians to be more vigilant in identification, cleaning, and obturation of all canals, which can improve the outcome of the treatment.

Conclusion

Obtaining these prevalence data is crucial because failure to recognize the presence of additional root canals during RCT may lead to inadequate removal of infected pulpal tissue and incomplete obturation of all root canals which eventually results in failure of the whole treatment.

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Conflicts of interest

There are no conflicts of interest.

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