ORIGINAL SCIENTIFIC ARTICLE

COMPLICATED ROOT CANAL MORPHOLOGY OF PERMANENT MANDIBULAR LATERAL INCISORS IS ASSOCIATED WITH THE PRESENCE OF A SECOND MESIOBUCCAL CANAL IN PERMANENT MAXILLARY FIRST MOLARS

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ABSTRACT

Many studies have been conducted in order to define the root canal morphology based on age, gender, ethnic and racial characteristics of the population. However, relations within morphological variations of certain groups of teeth have rarely been investigated. The aim of this study was to evaluate the root canal morphology of mandibular lateral incisors and to determine the association between their morphologic characteristics and the presence of a second mesiobuccal canal of maxillary first molars. Cone-beam computed tomography images from a pre-existing base were analyzed for the bilateral presence of both permanent mandibular lateral incisors and permanent maxillary first molars. Root canal morphology was analyzed according to the Vertucci classification. Associations of root canal morphologies between incisors and molars were calculated as probabilities using binary logistic regression analysis. In total, 126 mandibular lateral incisors and 126 maxillary first molars were included. 46% of all mandibular lateral incisors showed complicated root canal morphology and Vertucci type III canal configuration as the most frequent. Second mesiobuccal root canal was present in 62.7%. Root canal morphologies showed high level of bilateral symmetry in both tooth groups. The probability of a subject having complicated root canal morphology in lateral incisors was significantly higher when the second mesiobuccal canal was present. Clinicians should consider all available information on patients' root canal morphology when planning new endodontic treatment. Root canal morphology of permanent mandibular lateral incisors showed high association with the root canal morphology of permanent maxillary first molars.

Keywords: *cone-beam computed tomography, incisors, mesiobuccal root, molars, root canal morpholog.*

INTRODUCTION

The success of endodontic therapy relies on thorough cleaning, shaping and filling of root canal system. And thus the understanding of root canal morphology and its possible complexities decrease the incidence of procedural errors at any stage of endodontic treatment (1, 2). The introduction of cone-beam computed tomography into everyday dental practice has increased the availability of information on the root canal morphology in clinical conditions, which is in contrast to the previously used destructive laboratory techniques (3).

Permanent mandibular lateral incisors (PMLIs) are typically described as a single-rooted teeth with a single root canal (4). However, PMLIs with complex root canal system have been previously described, with varying incidence of two root canals depending on the studied population. The highest incidence was reported in Turkish population (63%) (5), which is in contrast to Chinese population (10%) (3). The permanent maxillary first molar (PMFM) is described as the tooth with the most variations in root and root canal morphology. It typically presents 3 roots with 3 or 4 root canals (6). The mesiobuccal root shows the highest complexity in root canal system. The incidence of the second mesiobuccal canal (MB2) varies from 36% to 75% depending on the population (7-15). Overall, difference in the incidence of multiple root canal complexities between Asian and Caucasian population is eminent, suggesting that morphological variations of root canal systems have racial basing (8).

Many studies have been conducted in order to define the root canal morphology based on age, gender, ethnic and racial characteristics of the population (8-10, 12). There are only a few studies regarding the association of morphological variations between different groups of teeth (2, 16). Recently, Wu et al. (17) examined the association between the presence of distolingual root in permanent mandibular molars and complex root canal morphology (PMLIs). However, to the authors' knowledge, the relation between the morphological variations of PMLIs and the variations of PMFMs has not yet been investigated.

THE AIM OF THE PAPER

The aim of this study was to evaluate the root canal configuration of PMLIs and to determine the association between root canal configuration of PMLIs and the presence of MB2 in PMFMs.

PATIENTS AND METHODS

Image Acquisition

All images analyzed in this study were retrieved from a pre-existing CBCT database. CBCT scans were made at the Department of Dentistry, Faculty of Medical Sciences, University of Kragujevac, Serbia from October 2014 to October 2018. Scans were stored in the Digital Imaging and Communications in Medicine (DICOM) format. The reasons for patient's imaging were different (prosthetic, surgical, orthodontic and endodontic), but not with the intention of using them in this study. The study protocol was approved by the Ethics Committee of the Faculty of Medical Sciences, University of Kragujevac, Serbia (protocol number: 01-15837), and it was conducted in accordance with the Helsinki Declaration and Guidelines for Good Clinical Practice.

The scans were obtained using Orthophos XG 3D device (Sirona Dental Systems GmbH, Bensheim, Germany) with a three-dimensional settings for recording, VOL1 HD (85kV/6mA, exposure time - 14.3 seconds) or VOL2 HD (85kV/10mA, exposure time - 5.0 seconds), and a voxel size of 160μm or 100μm, respectively.

Initially, 150 patient's CBCT scans were examined for the bilateral presence of PMLIs and PMFMs, and 63 images qualified for further analysis based on the previously described inclusion criteria (17):

1. PMLIs and PMFMs were fully visible
2. Completed root formation
3. Absence of root canal treatment or obturation material
4. Absence of crown, post and core restorations
5. Absence of visible external or internal root resorptions

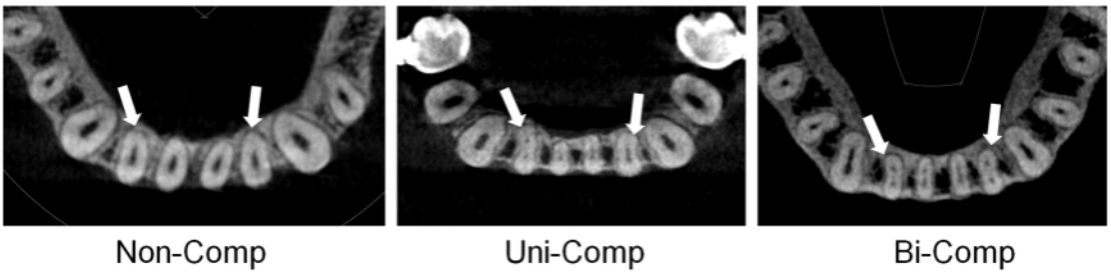
Configuration Analysis and Classification

CBCT images were analyzed using a software GALAXIS v1.9.4 (Sirona Dental Systems GmbH, Bensheim, Germany). Observations were conducted using a Philips LED monitor, sized 23-inch, with a resolution of 1920 x 1080 pixels, in a room with dim lighting. Brightness and contrast were adjusted using software.

Root canal configurations in PMLIs and in mesiobuccal roots of PMFMs were analyzed on axial cross-sections and classified according to the Vertucci classification (18). The presence of type I root canal configuration (i.e. single canal) was noted as non-complicated root canal, while the presence of other types (i.e. two canals) was noted as complicated root canal. The presence or absence of MB2 in mesiobuccal roots of PMFMs was noted for every individual CBCT image.

Based on the bilateral presence of the second root canal in PMLIs (complicated root canal morphology) and in PMFMs (MB2), all images were further classified in the following groups:

Figure 1. Examples of subjects with different presence of PMLIs with complicated root canal morphology on axial cross-sections. Subjects were dived into three following groups: Non-Comp, Uni-Comp, Bi-Comp.

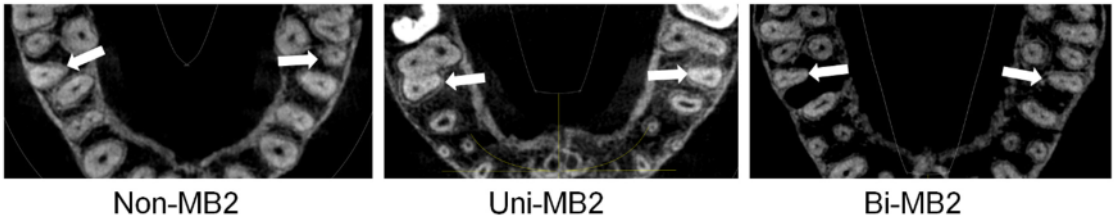


Non-Complicated (Non-Comp) - second root canals were absent in right or left PMLIs.

Unilateral Complicated (Uni-Comp) - second root canals were present in 1 PMLI (left or right); second root canal was absent in the other PMLI.

Bilateral Complicated (Bi-Comp) - second root canals were present in both left and right PMLIs.

Figure 2. Examples of subjects with different presence of PMFMs with MB2 on axial cross-sections. Subjects were dived into three following groups: Non-MB2, Uni-MB2, Bi-MB2.



Non-MB2 (Non-MB2) - MB2 was absent in mesiobuccal roots of both left and right PMFMs.

Unilateral MB2 (Uni-MB2) - MB2 was present in mesiobuccal root of 1 PMFM (left or right); MB2 was absent in the other PMFM.

Bilateral MB2 (Bi-MB2) - MB2 was present in mesiobuccal roots of both left and right PMFMs.

Statistical Analysis

Descriptive statistics were expressed as mean values and standard deviations, frequencies and percentages. In order to examine the relation within categorical variables, such as the presence of complicated root canal configuration in PMLIs and PMFMs, age (<27 and ≥27), gender (female or male), side (left or right) and the presence of MB2 (Non-MB2, uni-MB2 and bi-MB2) the chi-square test was used. The binary logistic regression analysis was used to further evaluate the independent effect of the categorical variables in the presence of complicated PMLI root canal morphology. The confidence interval (CI) was set to 95%. For all statistical analysis, a P value of <.05 was considered significant. Statistical analysis was performed using SPSS for Windows v20.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Out of 150 firstly examined patients' CBCT scans, 63 qualified for further analysis (126 PMLIs, and 126 PMFMs). Among these scans, 49.2% belonged to female, and 50.8% belonged to male patients. The patients' mean age was 26.29 ± 2.093, and 31.38 ± 2.015, respectively.

The frequency of PMLIs with complicated root canal morphology was 46% (58/126 teeth), present as type III configuration in 41.3%, and type II configuration in 4.8%. MB2 canal in PMFMs (i.e. complicated root canal morphology) was present in 62.7% (79/126 teeth). The most frequent root canal configuration in mesiobuccal roots of PMFMs was type II in 39.7%, followed by type I in 37.3% and type III in 12.7%. Less frequent were types V, VI, and IV present in 5.6%, 3.2%, and 1.6% respectively. There was no significant age difference in the presence of a complicated root canal (P = .699) and different types of a configuration in PMLIs

(P = .869). The gender difference was significant for complicated PMLIs (P = .001) and root canal configuration (P = .003). There was no significant side difference regarding above mentioned parameters (P = .284 and P = .543). The presence of the MB2 was significantly different depending on age (P = .013), but not significantly different depending on the gender (P = .490) or side (P = .357). The significant age, gender and side differences were found in the mesiobuccal root canal configuration (P=.021, .006, and .005 respectively) (Table 1).

The bilateral symmetry of the root canal morphology of PMLIs was 39.7% (25/63 scans) for non-Comp group, and 31.7% (20/63 scans) for bi-Comp group. Bilateral absence of MB2 in PMFMs (Non-MB2) was found in 23.8% (15/63 scans), while bi-MB2 was present in 49.2% (31/63 scans). Significant gender difference was found in the presence of bilateral root canal morphology for both PMLIs (P = .007) and PMFMs (P = .031). Also, bilateral symmetry showed significant age difference for the PMLIs (P = .038), but not for the PMFMs (P = .071). We also measured the bilateral presence of the same root canal configuration types in PMLIs and mesiobuccal roots of PMFMs. Same configuration types in PMLIs were found bilaterally in 69.9% (44/63 scans), while the mesiobuccal roots of PMFMs presented the bilateral configuration type symmetry in 30.2% (19/63 scans). The significant age difference was found only for PMLIs (P = .032) (Table 2).

The logistic regression analysis was adjusted for age, gender and side, and the frequency of complicated PMLIs was compared between the groups with absent or present MB2. The frequencies of complicated PMLIs in Uni-MB2 and Bi-MB2 groups, when compared to Non-MB2 group, were 7.733 (95%, 2.020 - 29.607, P = .003) and 11.662 (95%, 3.499 - 38.872, P < .001), respectively (Table 3).

Table 1. Frequency of PMLIs and PMFMs with complicated root canal morphology and differences in root canal system configurations related to age, gender and tooth side

		Root canal morphology, n (%)		*P*	Root canal system configuration n (%)						*P*
		Non-complicated	Complicated		Type I	Type II	Type III	Type IV	Type V	Type VI	
PMLIs	**Age**										
	<27	41(55.4)	33(44.6)	.699	41(55.4)	3(4.1)	30(40.5)	-	-	-	.869
	≥27	27(51.9)	25(48.1)		27(51.9)	3(5.8)	22(42.3)	-	-	-	
	Gender										
	Female	43(69.4)	19(30.6)	.001*	43(69.4)	2(3.2)	17(27.4)	-	-	-	.003*
	Male	25(39.1)	39(60.9)		25(39.1)	4(6.3)	35(54.7)	-	-	-	
	Side										
	Left	31(49.2)	32(50.8)	.284	31(49.2)	3(4.8)	29(46)	-	-	-	.543
	Right	37(58.7)	26(41.3)		37(58.7)	3(4.8)	23(36.5)	-	-	-	
	Total	68(54)	58(46)		31(54)	6(4.8)	52(41.3)	-	-	-	
PMFMs	**Age**										
	<27	21(28.4)	53(71.6)	.013*	21(28.4)	33(44.6)	10(13.5)	-	7(9.5)	3(4.1)	.021*
	≥27	26(50)	26(50)		26(50)	17(32.7)	6(11.5)	2(3.8)	-	1(1.9)	
	Gender										
	Female	25(40.3)	37(59.7)	.490	25(40.3)	17(27.4)	10(16.1)	-	7(11.3)	3(4.8)	.006*
	Male	22(34.4)	42(65.6)		22(34.4)	33(51.6)	6(9.4)	2(3.1)	-	1(1.6)	
	Side										
	Left	26(41.3)	37(58.7)	.357	26(41.3)	26(41.3)	2(3.2)	-	5(7.9)	4(6.3)	.005*
	Right	21(33.3)	42(66.7)		21(33.3)	24(38.1)	14(22.2)	2(3.2)	2(3.2)	-	
	Total	47(37.3)	79(62.7)		47(37.3)	50(39.7)	16(12.7)	2(1.6)	7(5.6)	4(3.2)	

PMLIs - permanent mandibular lateral incisors; PMFMs - permanent maxillary first molars; n - number of cases; * Statistically significant with the level of $P < .05$

Table 2. Bilateral symmetry in complicated root canal morphology and in root canal system configurations of PMLIs and PMFMs related to age and gender.

PMLIs	Bilateral symmetry of complicated root canal morphology			*P*	Bilateral symmetry in root canal configuration types		*P*
	Non-Comp, n(%)	Uni-Comp, n(%)	Bi-Comp, n(%)		Same type, n(%)	Different type, n(%)	
Age							
<27	13(35.1)	15(40.5)	9(24.3)	.038*	22(59.5)	15(40.5)	.032*
≥27	12(46.2)	3(11.5)	11(42.3)		22(84.6)	4(15.4)	
Gender							
Female	16(51.6)	11(35.5)	4(12.9)	.007*	20(64.5)	11(35.5)	.365
Male	9(28.1)	7(21.9)	16(50)		24(75)	8(25)	
Total	25(39.7)	18(28.6)	20(31.7)		44(69.8)	19(30.2)	
PMFMs	Non-MB2, n(%)	Uni-MB2, n(%)	Bi-MB2, n(%)		Same type, n(%)	Different type, n(%)	
Age							
<27	11(29.5)	21(56.8)	5(13.5)	.071	10(27)	27(73)	.205
≥27	6(23.1)	10(38.5)	10(38.5)		11(42.3)	15(57.7)	
Gender							
Female	6(19.4)	13(41.9)	12(38.7)	.031*	8(25.8)	23(74.2)	.212
Male	9(28.1)	4(12.5)	19(59.4)		13(40.6)	19(59.4)	
Total	15(23.8)	17(27)	31(49.2)		21(33.3)	42(66.7)	

PMLIs - permanent mandibular lateral incisors; PMFMs - permanent maxillary first molars;
Non-Comp - Bilateral absence of the complicated root canal morphology; Uni-Comp-Unilateral presence of complicated root canal morphology; Bi-Comp - Bilateral presence of complicated root canal morphology;
Non-MB2 - Bilateral absence of a second mesiobuccal canal; Uni-MB2-Unilateral presence of second mesiobuccal canal; Bi-MB2-Bilateral presence of a second mesiobuccal canal; n - number of cases;
* Statistically significant with the level of $P < .05$

Table 3. The logistic regression analysis of the association between age, gender, tooth side, and the presence of second mesiobuccal canal in PMFMs with the presence of complicated root canal morphology in PMLIs.

	PMLIs			
		95% CI		
	Adjusted OR	Lower	Upper	*P*
Age				
<27	Ref			
≥27	1.231	.483	3.138	.664
Gender				
Female	Ref			
Male	4.511	1.757	11.581	.002*
Side				
Left	Ref			
Right	.602	.267	1.357	.221
MB2 Group				
Non-MB2	Ref			
Uni-MB2	7.733	2.02	29.607	< .001*
Bi-MB2	11.662	3.499	38.872	< .001*

* Statistically significant with the level of P < .05
PMLIs - permanent mandibular lateral incisors; CI - Confidence interval set at 95%;
OR - odds ratio; Ref - Referent category; Non-MB2 - Bilateral absence of second mesiobuccal canal;
Uni-MB2 - Unilateral presence of second mesiobuccal canal;
Bi-MB2 - Bilateral presence of second mesiobuccal canal;

DISCUSSION

Inadequate cleaning and shaping of root canals with complicated morphology is a major cause of failure of endodontic treatment (19). PMLIs and PMFMs are one of the most challenging teeth to be treated thanks to the variations in their root canal morphology (20-22). The root canal morphology has been previously extensively studied in vitro with the use of method of clearing and staining (18), and more recently with the use of micro-CT (23, 24). In clinical setting the root canal morphology could be assessed with the use of retroalveolar radiology, dental operating microscope or CBCT. While the first two methods provide the vast information about root canals, CBCT is only which provides the clinician with the information about all aspects of root canal morphology throughout the whole canal working length (22). In our study, we used CBCT scans acquired by using two high definition settings for imaging with a voxel size of 0.16mm or 0.10mm. This voxel size with the use of high definition settings is reported to be adequate for proper root canal visualization (25).

Complicated root canal morphology of PMLIs has been previously described whit the varying incidence in different populations ranging from 11% to 40% (3, 4, 9, 24, 26, 27). Martins et al. (8) suggested that complicated root canal morphology is associated with the population's race or ethnicity, showing that Caucasians have higher incidence of complicated PMILs (30%) then Asians (5%). In line with this claim are the results of the study in Chinese population showing the frequency of complicated PMLIs in 10%. Our results (Table 1) correspond to results in Portuguese (30%) (9), Israeli (38%) (26), Brazilian (40%) (4), and Turkish population (48%) (28). In accordance to our results (Table 1), previous studies showed the highest frequency of type I root canal configuration, followed by type III as the next most frequent (3,4,9,26-28). Other than race and ethnicity, previous studies related the differences of root canal configurations to gender. Our study showed a significant gender difference (Table 1) where male subjects tend to have more complicated PMLIs, as shown in previous studies (26, 28, 29). We furtherly supported this claim analyzing the adjusted OR (Table 3), which showed that male subjects have over 4 times higher chance of presenting complicated PMLIs than female subjects.

The mesiobuccal root of PMFMs is reported having the highest incidence of variations in root canal configuration compared to distobuccal and palatal roots (30). The absence of MB2 could be rather called a variation than its presence, considering that the most previous studies show the incidence of MB2 to be higher than 50% (7, 10, 12, 14), and to be as high as 75% (13). Lower presence was shown in fewer studies, such as in the Malaysian (36%) (15) and in Taiwanese populations (46%) (11). The presence of MB2 was not found to be gender related in our study (Table 1), as shown by other authors (11, 12, 15). However, we found the significant gender difference in the root canal configurations (Table 1). Although both genders showed the highest frequency of type I and type II, male subjects presented type II configuration more frequent than female, while female subject presented more type III, and type V in their PMFMs compared to men. To analyze the influence of subject's age on root canal configurations, we selected to divide the subjects into two groups according to the median age value of studied sample. By analyzing those two groups, we found the age difference in presence of MB2, having shown that younger subject had more MB2 present in their PMFMs (Table 1). Previous studies also reported that the frequency of MB2 declines with the rise in subject's age (7, 31), but unlike in our study, their studies presented higher sample size with more heterogeneous age groups.

As we previously discussed, many studies have been conducted to define the root canal morphology based on the populations' race, ethnicity, gender, and age. Even though population studies could help clinician on what morphology should be expected in a patient, every case should be analyzed individually and treatment plan should be selected on the basis of the acquired information on that individual. In our study, we analyzed the bilateral symmetry of complicated and non-complicated root canal morphology and different types of root canal configurations in each subject (Table 2). Same root canal morphology of PMLIs and PMFMs was presented symmetrically in 71.4% (45/63 subjects) and 73% (46/63 subjects), respectively (Table 2). PMLIs showed a high bilateral symmetry in root canal configuration types (69.8%) wile in PMFMs configurations were found to be less symmetrical (33.3%) (Table 2). Bilateral symmetry of root canal morphology was found to be gender related previously (11,32), as it was in our study. Males showed higher symmetry in both PMLIs and PMFMs. Only recently, a few studies have been conducted in order to associate the root canal morphology of one group of teeth to another (2,16,17). Two of these studies found that the presence of distolingual root in permanent mandibular first molars was associated with the presence of complicated root canal morphology in permanent mandibular central incisors as well as in PMLIs (16, 17). In that manner, we tried to associate the presence of MB2 with the complicated root canal morphology in PMLIs by conducting binary logistic regression analysis. Our results (Table 3) showed that individuals presenting the MB2 in PMFMs unilaterally or bilaterally, have 7 and 11 times higher chance of having complicated PMLIs, respectively, compared to subjects with bilateral absence of MB2. The cause of this association is yet unknown, but could be found in the timing of their root formation, as the most of developmental stages in the formation of PMLIs and PMFMs appear at the similar time (33). Previously, it has been shown that if the factors that could compromise tooth development are introduced at a certain period of the dentition formation, it is most likely that developmental defects, such as molar-incisor hypomineralization, will appear on both permanent molars and incisors (34).

CONCLUSION

Clinicians should be aware of possible root canal complexities and the differences in their presentations. Our study showed high frequency of complicated root canal morphology in PMLIs and PMFMs that fit in the range for Caucasian population. Female subjects are more prone to show non-complicated morphology when compared to male subject. Also, if the presence of MB2 is found in PMFMs, clinician should expect the presence of a complicated root morphology in PMLIs when planning the endodontic treatment of these teeth.

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