Differences on the Root and Root Canal Morphologies between Asian and White Ethnic Groups Analyzed by Cone-beam Computed Tomography

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Abstract

Introduction: Populations from different geographic regions and ethnic backgrounds may present differences in dental morphology. The aim of this study was to compare the differences in root and root canal configurations on Asian and white subpopulations using cone-beam computed tomographic imaging. **Methods:** Information from Asian and white patients was retrieved from 2 cone-beam computed tomographic imaging databases in China and Western Europe. Two calibrated observers collected data regarding the number of roots and Vertucci root canal system configuration for all groups of teeth. A total of 15,655 teeth were analyzed. The *z* test for independent groups was used to analyze differences between the groups. The significance level was considered at a P value < .05. Reliability tests were performed between observers. **Results:** Differences were noted in the number of roots per tooth in 6 groups of teeth. The Asian group showed a higher prevalence of single-root configurations in maxillary first premolars (83.2%) and mandibular second molars (45.4%) when compared with whites with 48.7% and 14.3%, respectively. Moreover, 3-rooted configurations in mandibular first molars were more common in Asians (25.9%) compared with whites (2.6%). Seventeen of the 20 analyzed roots had a higher prevalence of Vertucci type I configuration in Asians. Maxillary first molars with second mesiobuccal root canals were more commonly found in whites than in Asians (71.3% and 58.4%, respectively). A similar situation was found in maxillary second molars. **Conclusions:** The Asian ethnic group presented a higher prevalence of Vertucci type I configuration, whereas the white group displayed a higher number of multiple root canal system morphologies. A clinician should be aware of these differences when treating patients from these ethnic groups. *(J Endod 2018;44:1096–1104)*

Key Words

Anatomy, cone-beam computed tomography, ethnic, morphology, prevalence, root canal

Significance

Asians and whites present differences in the root and root canal system configurations. Whites are more prone to present multiple root canal systems, whereas Asians are more prone to present 3-root configurations and C-shaped root canals on mandibular first and second molars, respectively.

Asians and whites are 2 of the most prevalent ethnic groups worldwide. Several body morphologic differences, such as tibia shaft anatomy (1) and retinal shape (2), and differences in disease prevalence, such as peripheral arterial disease (3), between these groups have been previously documented. In the available literature, only 1 article from Guo et al (4) mentioned differences regarding root canal system anatomy between both ethnic groups. Guo et al performed an evaluation of maxillary first molar morphology in a North American subpopulation. One of the variables analyzed in the study was the difference among 5 ethnic groups (black, Asian, Hispanic, white [non-Hispanic], and other) regarding the presence of the second mesiobuccal (MB2) root canal and morphology. Statistical differences were not identified regarding the presence/absence of the MB2 root canal among ethnic groups. However, differences were found in the mesiobuccal root canal morphology. Asians presented a higher prevalence of Vertucci type I (35.0%) and type IV (45.0%) configurations when compared with the white group (type I: 23.4%, type IV: 36.3%). The opposite was also reported regarding Vertucci type II, which was more commonly found in whites (36.3%) compared with Asians (15.0%). Another recent study from von Zuben et al (5) compared mandibular second molar C-shaped root canal system morphology prevalence among 9 geographic regions. Although not clearly linking any geographic region to a specific ethnic group, the authors found a statistically higher prevalence of mandibular second molar C-shaped morphologies in China (44.0%) when compared with any other region. This study included 3 Western European countries (Portugal [8.3%], Spain [11.0%], and England [7.8%]) with a high white prevalence.

Studies comparing root canal morphologies of different regions in the globe are very rare. To the best of the authors' knowledge, with the exception of the study by von Zuben et al (5), only the article by Torres et al (6) compared root canal anatomy of the mandibular first and second molars between Belgian and Chilean subpopulations. The

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authors did not evaluate statistical significances between groups. However, strong prevalence differences were found in the Vertucci type II configuration in the distal root of mandibular first molars, which was present in 5.0% of Belgians and 18.9% of Chileans.

Another morphologic characteristic that is usually associated with Asian populations, with a traditionally higher prevalence when compared with other populations, is the presence of a second distal root in mandibular first molars. This anatomic feature prevalence may be as high as 22.3% in Korea (7), 25.6% in Taiwan (8), and 29.7% in China (9), whereas in other regions, it may be as low as 0.5% (Turkey) (10), 0.8% (Spain) (11), and 2.2% (Portugal) (12). Although this difference seems notorious, there is no available scientific study performed with calibrated observers from a single research group that compared both ethnic groups. This characteristic or any other feature from any other tooth, with the exception of the maxillary first molar as reported by Guo et al (4), has ever been reported. The possible root canal morphologic differences between these 2 ethnic groups, although stated as possible, were not yet addressed in the literature. Moreover, keeping in mind that root canal therapy requires a full debridement and disinfection of the root canal system, knowing the root canal configuration prevalence when treating these patients is important. The aim of this study was to compare the differences in root and root canal configurations in Asian and white subpopulations using cone-beam computed tomographic (CBCT) imaging.

Material and Methods

CBCT examinations of 790 patients were collected from 2 existing databases in 2 health centers in Suzhou (China) and Lisbon (Portugal). CBCT scans from patients that would physically fit in the Asian ethnic group profile in Suzhou and in the white ethnic group profile in Lisbon were selected. The scans were performed for several reasons other than this study. One single observer in each region analyzed the examinations retrospectively. Although the CBCT machines were different in both regions, a Kodak scanner (Kodak 9500; Carestream, Atlanta, GA) in Suzhou and a Planmeca scanner (Planmeca Promax; Planmeca, Helsinki, Finland) in Lisbon, they both share the same voxel size (0.20 mm) and field of view (full arch). All the CBCT examinations were analyzed with proper visualization software. Although the visualization software was different in both regions, they presented similar functions that allowed an equal methodology of assessing the CBCT scans. Table 1 summarizes both CBCT characteristics and settings.

Teeth with previous endodontic treatment, third molars, teeth with immature apices or root resorptions, and scans with image artifacts were excluded. All included teeth were analyzed in 3 planes (ie, coronal, sagittal, and axial), and, in order to facilitate the interpretation of root canal anatomy, both observers were allowed to change the software visualization settings.

A total of 15,655 teeth were included in this study. The analyzed teeth were divided into 2 major groups, Asians and whites, depending on the region of origin. The Asian sample included 3330 teeth from 120 patients (54 men and 66 women with an average age of 28 years), whereas the white sample included 12,325 teeth from 670 patients (243 men and 427 women with an average age of 51 years).

According to previous studies (12), for each tooth, the following information was recorded:

1. The number of roots
2. Root canal system configuration according to Vertucci classification (13) (in the molar teeth, each root was evaluated individually)
3. The total number of root canals per root (they were classified as having "1 root canal," "2 root canals," or "3 root canals" depending on the root canal Vertucci classification)
4. Exclusively for mandibular molars, the presence of C-shaped configurations, according to Fan et al's criteria (14), was also recorded

Statistical Analysis

The collected data were introduced into SPSS software (Version 22; IBM Corp, Armonk, NY). The primary outcomes were root canal configuration and the number of roots, whereas the predictive variable was ethnicity. The proportion of each anatomic configuration for each group of teeth was calculated as well as the lower and upper limits of the 95% confidence interval (CI) for each proportion. The z test for proportions was used to analyze differences between ethnicities for each group of teeth. For all compared groups, a P value $< .05$ was considered significant.

The Cohen kappa test was used to determine both interrater (2 raters) and intrarater reliability. For the interrater test, the CBCT images of the same 140 teeth were evaluated by the 2 observers. For the intrarater test, the observer from Suzhou performed the evaluation of 112 teeth (which represents 3.36% of the total Asian sample, corresponding to the 4 initial patients), whereas the observer from Lisbon performed the evaluation of 589 teeth (which represents 4.78% of the total white sample, corresponding to the initial 32 patients). These teeth were evaluated twice with a 1-month interval between observations. Both reliability tests were performed for all evaluated teeth (all Vertucci configurations) and for the same group of teeth in which the Vertucci type I configurations would be excluded (non–type I Vertucci configurations) so the reliability for more complex anatomic configurations could be determined also.

For the purposes of this study, the observers were considered reliable for both inter- and intrarater reliability tests if the obtained kappa coefficient of agreement was equal or superior to 0.81 (almost perfect agreement). Table 2 summarizes the reliability tests results.

Results

Root Morphology

Six of the 14 groups of teeth that were analyzed presented significant differences between ethnic groups regarding the number of roots per tooth. Four of those 6 groups of teeth presented a significantly higher number of single-root configurations in the Asian sample. The prevalence of the single-rooted maxillary first premolar configuration was 83.2% (95% CI, 78.5%–87.9%) and 48.7% (95%

TABLE 1. Cone-beam Computed Tomographic (CBCT) Characteristics and Geographic Location to Each Ethnicity

Ethnicity	Location	Observer	CBCT Model	CBCT voxel size	CBCT FOV	CBCT settings	Visualization software
Asian	Suzhou (China)	Y.G.	Kodak 9500	200 μm	Full arch	90 kV, 10 mA, 10.8 seconds	CS 900 3D imaging
White	Lisbon (Portugal)	J.M.	Planmeca Promax	200 μm	Full arch	80 kV, 15 mA, 12.0 seconds	Planmeca Romexis

FOV, field of view.

TABLE 2. Intrarater and Interrater Cohen Kappa Test Values

	All Vertucci configurations			Non–type I Vertucci configurations*		
	Intrarater reliability (white)	Intrarater reliability (Asian)	Interrater reliability (white vs Asian)	Intrarater reliability (white)	Intrarater reliability (Asian)	Interrater reliability (white vs Asian)
Teeth analyzed twice (*n*)	589	112	140	188	35	61
Kappa value	0.879	0.947	0.888	0.823	0.922	0.810
Asymptotic standard error	0.018	0.030	0.033	0.033	0.054	0.57

*We excluded all Vertucci type I classifications detected at the first evaluation.

CI, 45.0%–52.4%) for the Asian and white groups, respectively, whereas the prevalence of the single-rooted mandibular second molar was 45.4% (95% CI, 39.1%–51.7%) and 14.3% (95% CI, 11.7%–16.9%) for the Asian and white groups, respectively. Although presenting smaller differences, the number of single-rooted teeth was also significantly higher in Asian patients in maxillary second premolars and mandibular canines (Table 3).

Both maxillary and mandibular first molars presented a significantly lower number of roots in the white group. In the mandibular first molar, the prevalence of a third root was 25.9% (95% CI, 20.1%–31.7%) and 2.6% (95% CI, 1.2%–4.0%) for the Asian and white groups, respectively (Table 3) (radix entomolaris in all cases). In the mandibular second molar, the prevalence of a third root was 0.8% (95% CI, 0%–1.9%) and 2.6% (95% CI, 1.4%–3.8%) for the Asian and white groups, respectively (Table 3). In the Asian group, both cases were radix entomolaris, whereas in the white group the distribution was 3 radix paramolaris, 4 radix entomolaris, 4 extra mesiolingual roots, and 7 mesial roots divided into 2 equal single-canal roots.

Root Canal Configuration

With the exception of both maxillary incisors and the distobuccal root of maxillary second molars, which presented 100% of cases with Vertucci type I (1) configurations in both ethnics groups, all other 17 analyzed roots presented a significantly higher number of Vertucci type I configurations in the Asian group (Fig. 1). The presence of the MB2 root canal was higher in whites with a prevalence of 71.3% (95% CI, 67.4%–75.2%) and 43.8% (95% CI, 39.8%–47.8%) for maxillary first and second molars, respectively, whereas the Asian group presented 58.4% (95% CI, 52.1%–64.7%) and 18.5% (95% CI, 12.9%–24.1%) for maxillary first and second molars, respectively. The presence of the 3-root canal configuration per root, although remaining an uncommon finding, presented a higher prevalence in the white group. Tables 4 and 5 summarize the root canal system configuration and the total number of root canals per root.

C-shaped Mandibular Molar

The C-shaped root canal configuration was not found in any mandibular first molar of the Asian group and was a rare finding for the white group (0.6% [95% CI, 0%–1.3%]), presenting no statistical difference between both ethnic groups. The prevalence of mandibular second molar C-shaped root canal systems was significantly higher for the Asian group (43.3% [95% CI, 37.0%–49.6%]) compared with the white group (8.7% [95% CI, 6.6%–10.8%]).

Discussion

One of the main objectives of root canal therapy is the full debridement and disinfection of the root canal system. To maximize a successful approach for doing so, a thorough knowledge of root canal anatomy is advisable. Being able to anticipate possible anatomic characteristics considering the ethnic profile might be a clinical advantage for the clinician who is performing the treatment.

TABLE 3. The Number of Teeth and the Number of Roots in Each Ethnic Group

	Total sample (*n*)		Number of roots, *n* (%)							
			1		2		3		4	
Tooth group	Asian	White	Asian	White	Asian	White	Asian	White	Asian	White
Maxillary central incisor	240	907	240 (100)	907 (100)	—	—	—	—	—	—
Maxillary lateral incisor	240	937	240 (100)	937 (100)	—	—	—	—	—	—
Maxillary canine	240	999	240 (100)	999 (100)	—	—	—	—	—	—
Maxillary 1st premolar*	238	714	198 (83.2)†	348 (48.7)†	40 (16.8)†	351 (49.2%)†	†	15 (2.1)†	—	—
Maxillary 2nd premolar*	239	618	237 (99.2)†	585 (94.7)†	2 (0.8)†	33 (5.3)†	—	—	—	—
Maxillary 1st molar*	239	567	—	3 (0.5)	1 (0.4)†	48 (8.5)†	238 (99.6)†	516 (91.0)†	—	—
Maxillary 2nd molar	240	802	24 (10.0)	107 (13.3)	27 (11.3)	106 (13.2)	185 (77.1)	585 (72.9)	4 (1.7)	4 (0.5)
Mandibular central incisor	240	1203	240 (100)	1203 (100)	—	—	—	—	—	—
Mandibular lateral incisor	240	1234	240 (100)	1234 (100)	—	—	—	—	—	—
Mandibular canine*	240	1244	238 (99.2)†	1207 (97.0)†	2 (0.8)†	37 (3.0)†	—	—	—	—
Mandibular 1st premolar	238	1089	238 (100)	1087 (99.8)	—	2 (0.2)	—	—	—	—
Mandibular 2nd premolar	236	858	236 (100)	857 (99.9)	—	1 (0.1)	—	—	—	—
Mandibular 1st molar*	220	466	—	3 (0.6)	163 (74.1)†	451 (96.8)†	57 (25.9)†	12 (2.6)†	—	—
Mandibular 2nd molar*	240	687	109 (45.4)†	98 (14.3)†	129 (53.8)†	571 (83.1)†	2 (0.8)†	18 (2.6)†	—	—
Total (in groups)	3330	12,325								
Total (all teeth)	15,655									

*Teeth presenting differences in the number of roots between ethnic groups.

†Differences between ethnic groups ($P < .05$).

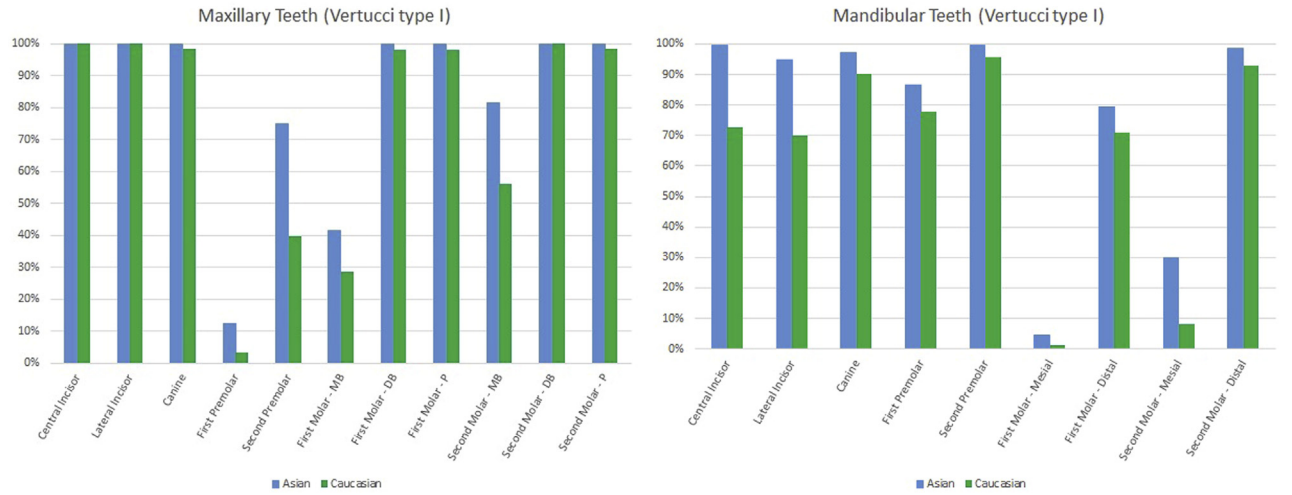

Figure 1. A graphic distribution of Vertucci type I configuration in all analyzed roots according to ethnic group.

Few differences between Asian and white ethnic groups have been reported or speculated; the only available results have been presented by Guo et al (4) and von Zuben et al (5) regarding the characteristics of maxillary first molars with MB2 root canals and mandibular second molar C-shaped prevalence, respectively. Both studies used CBCT technology as a source of data. This technology has been widely used by several researchers to study root canal system morphology (15–19). Keeping in mind the *in vivo* characteristics of the methodology, it might be regarded as the most adequate imaging technique to study the prevalence of anatomic characteristics. Other *ex vivo* methods have been used to study root canal anatomy, such as clearing (13) and micro–computed tomographic (micro-CT) imaging (14). Because of the *ex vivo* nature of these methods, the percentages reported in these studies might be influenced by the teeth that need to be extracted or if it was possible to extract them intact. Moreover, CBCT imaging has been proven to be reliable for analyzing the Vertucci classification when compared with the gold standard of micro-CT imaging (20) although it does not present the high-resolution detail of micro-CT imaging (20). Furthermore, CBCT imaging, when compared with micro-CT imaging or the clearing technique, allows large sample size analysis, allows *in vivo* collection of data in all teeth from a single patient, is not expensive, and is faster to be acquired.

The present study results for root and root canal morphology of maxillary anterior teeth are in accordance with previous studies from several regions of the globe (16, 21, 22). No data were available yet in Asians before this study; however, the morphology of these teeth seems to be quite similar worldwide. The same does not seem to happen with mandibular anterior teeth. The present study describes a Vertucci type I (single root canal) prevalence of 99.6% and 95.0% in Asians for mandibular central and lateral incisors, respectively, which was significantly higher when compared with the white group, which presented 72.6% and 70.1%. Comparison with previous studies is difficult because most of them do not mention ethnicity and only refer to the country where the study was performed. Nonetheless, taking into consideration the ethnic background of the studied regions, the results for the mandibular incisors corroborate previously published studies in which it was possible to verify that Vertucci type I has a higher prevalence in China (96.2% [23], 93.3% [24], and 91.1% [25], and 89.4% [23], 82.5% [24], and 82.4% [25] for mandibular central and lateral incisors, respectively) compared with predominantly white countries such as Brazil (21) (65.0% and 58.0% for central and lateral incisors, respectively) and France (22) (87.0% and 86.4% for central and lateral incisors, respectively). Moreover, the previously reported prevalence of the type I configuration is higher in Chinese studies than in any other regions including Iran (26), Turkey (27), Georgia (28), and India (29). The same finding was observed for mandibular canines in the present study. These results are once more supported by previous studies in which the occurrence of a Vertucci type I root canal in mandibular canines is recurrently higher in Chinese studies (97.0% [24], 95.8% [23], and 93.7% [30]) compared with predominantly white countries (78.0% in Brazil [21]) or any other region (66.8% in Georgia [28], 71.8% in Iran [26], 79.6% in India [31], and 89.7% in Israel [32]).

In the present study, maxillary first premolars presented a significantly higher prevalence of single-root morphologies in the Asian group (83.2%) and a higher prevalence of 3-rooted configurations in the white group (2.1%). These results are in accordance with previous studies because the highest previously documented prevalence of single-rooted morphologies comes from a Chinese study (33) with 66.0% of cases, and the highest prevalence of 3-rooted configurations was reported in a French study (22) with a rate of 4.2%. Regarding the root canal configuration in both maxillary premolars, a significantly higher prevalence of single-root canal systems was found in the Asian group. These results are in accordance with the majority of previous studies addressing countries with Asian or white backgrounds. Previous studies reported a Vertucci type I prevalence of 14.3% in China (33), 25.1% in Spain (15), 13.9% in France (22), 6.0% in Brazil (21), and 3.9% in Germany (34) and reported 45.4% in China (35), 66.7% in France (22), 39.3% in Spain (15), 25.0% in Brazil (21), and 14.3% in Germany (34) for maxillary first and second premolars, respectively. Regarding mandibular premolars, the Asian group presented a higher prevalence of Vertucci type I configuration, a finding basically in accordance with previous studies that showed an equal or higher prevalence of the type I configuration in Chinese studies (20, 36–38) compared with predominantly white countries such as France, Brazil, Spain, and Germany (21, 22, 34, 39).

As for the mesiobuccal root of maxillary first molars, the present study reports a significantly higher prevalence of Vertucci type I root canal configuration in the Asian group and a higher prevalence of MB2 root canals in the white group. These findings are contradictory to

TABLE 4. Root Canal Configuration and the Number of Root Canals of Maxillary Teeth on Each Ethnic Group

Anatomic Configuration	Maxillary teeth																					
	Central Incisor		Lateral Incisor		Canine*		First Premolar*		Second Premolar*		First molar*†						Second molar*†					
											Mesiobuccal		Distobuccal		Palatal		Mesiobuccal		Distobuccal		Palatal	
	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
Root canal configuration																						
Type I (1-1)	240 (100)	907 (100)	240 (100)	937 (100)	240 (100)	985 (98.6)	29 (12.2)	24 (3.4)	179 (74.9)	246 (39.8)	99 (41.6)	148 (28.7)	238 (100)	506 (98.1)	238 (100)	507 (98.3)	154 (81.5)	331 (56.2)	189 (100)	589 (100)	189 (100)	581 (98.6)
Type II (2-1)	—	—	—	—	—	11 (1.1)	54 (22.7)	122 (17.1)	36 (15.1)	177 (28.6)	15 (6.3)	230 (44.6)	—	7 (1.4)	—	2 (0.4)	12 (6.3)	157 (26.7)	—	—	—	2 (0.3)
Type III (1-2-1)	—	—	—	—	—	2 (0.2)	10 (4.2)	2 (0.3)	2 (0.8)	13 (2.1)	—	5 (1.0)	—	1 (0.2)	—	7 (1.4)	—	5 (0.8)	—	—	—	6 (1.0)
Type IV (2-2)	—	—	—	—	—	1 (0.1)	131 (55.0)	487 (68.2)	18 (7.5)	106 (17.2)	119 (50.0)	83 (16.1)	—	—	—	—	18 (9.5)	45 (7.6)	—	—	—	—
Type V (1-2)	—	—	—	—	—	—	14 (5.9)	7 (1.0)	4 (1.7)	29 (4.7)	5 (2.1)	10 (1.9)	—	1 (0.2)	—	—	4 (2.1)	22 (3.7)	—	—	—	—
Type VI (2-1-2)	—	—	—	—	—	—	—	33 (4.6)	—	40 (6.5)	—	31 (6.0)	—	1 (0.2)	—	—	—	25 (4.2)	—	—	—	—
Type VII (1-2-1-2)	—	—	—	—	—	—	—	—	—	—	—	1 (0.2)	—	—	—	—	—	1 (0.2)	—	—	—	—
Type VIII (3-3)	—	—	—	—	—	—	—	5 (0.7)	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other 2 root canal types	—	—	—	—	—	—	—	3 (0.4)	—	4 (0.6)	—	6 (1.2)	—	—	—	—	—	2 (0.3)	—	—	—	—
Other 3 root canal types	—	—	—	—	—	—	—	31 (4.3)	—	3 (0.5)	—	2 (0.4)	—	—	—	—	1 (0.5)	1 (0.2)	—	—	—	—
Number of root canals‡																						
1 root canal	240 (100)	907 (100)	240 (100)	937 (100)	240 (100)§	985 (98.6)§	29 (12.2)§	24 (3.4%)§	179 (74.9)§	246 (39.8)§	99 (41.6)§	148 (28.7)§	238 (100)§	506 (98.1)§	238 (100)§	507 (98.3)§	154 (81.5)§	331 (56.2)§	189 (100)	589 (100)	189 (100)§	581 (98.6)§
2 root canals‖	—	—	—	—	—§	14 (1.4)§	209 (87.8)	654 (91.6)	60 (25.1)§	369 (59.7)§	139 (58.4)§	366 (70.9)§	—§	10 (1.9)§	—§	9 (1.7)§	34 (17.9)§	257 (43.6)§	—	—	—§	8 (1.4)§
3 root canals¶	—	—	—	—	—	—	—§	36 (5.0)§	—	3 (0.5)	—	2 (0.4)	—	—	—	—	1 (0.5)	1 (0.2)	—	—	—	—

*Teeth presenting differences in the number of root canals between ethnic groups.

†Only upper molars with 3 independent roots.

‡Only the "number of root canals" was submitted to *z* test calculation.

§Differences between ethnic groups ($P < .05$).

‖All Vertucci configuration types with maximum 2 canals combined.

¶All Vertucci configuration types with maximum 3 canals combined.

TABLE 5. Root Canal Configuration and the Number of Root Canals of Mandibular Teeth on Each Ethnic Group

Anatomic Configuration	Mandibular teeth, *n* (%)																	
	Central Incisor*		Lateral Incisor*		Canine*		First Premolar*		Second Premolar*		First molar*†				Second molar*†			
											Mesial		Distal		Mesial		Distal	
	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
Type I (1-1)	239 (99.6)	873 (72.6)	228 (95.0)	865 (70.1)	233 (97.1)	1122 (90.2)	206 (86.6)	846 (77.7)	235 (99.6)	821 (95.7)	10 (4.5)	5 (1.1)	175 (79.5)	328 (70.8)	39 (29.8)	47 (8.0)	129 (98.5)	547 (92.9)
Type II (2-1)	—	29 (2.4)	7 (2.9)	75 (6.1)	4 (1.7)	41 (3.3)	—	27 (2.5)	1 (0.4)	7 (0.8)	27 (12.3)	217 (46.9)	12 (5.5)	55 (11.9)	39 (29.8)	370 (62.8)	1 (0.8)	5 (0.8)
Type III (1-2-1)	1 (0.4)	289 (24.0)	2 (0.8)	285 (23.1)	1 (0.4)	32 (2.6)	—	58 (5.3)	—	11 (1.3)	8 (3.6)	—	7 (3.2)	44 (9.5)	15 (11.5)	30 (5.1)	—	23 (3.9)
Type IV (2-2)	—	1 (0.1)	—	—	1 (0.4)	17 (1.4)	1 (0.4)	16 (1.5)	—	4 (0.5)	169 (76.8)	194 (41.9)	17 (7.7)	13 (2.8)	29 (22.1)	114 (19.3)	—	3 (0.5)
Type V (1-2)	—	4 (0.3)	3 (1.3)	3 (0.2)	1 (0.4)	31 (2.5)	30 (12.6)	133 (12.2)	—	12 (1.4)	6 (2.7)	18 (3.9)	9 (4.1)	14 (3.0)	9 (6.9)	3 (0.5)	1 (0.8)	11 (1.9)
Type VI (2-1-2)	—	—	—	—	—	—	—	—	—	—	—	—	—	5 (1.1)	—	10 (1.7)	—	—
Type VII (1-2-1-2)	—	6 (0.5)	—	3 (0.2)	—	—	—	2 (0.2)	—	—	—	—	—	1 (0.2)	—	—	—	—
Type VIII (3-3)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other 2 root canal types	—	1 (0.1)	—	2 (0.2)	—	1 (0.1)	—	1 (0.1)	—	—	—	4 (0.9)	—	3 (0.6)	—	2 (0.3)	—	—
Other 3 root canal types	—	—	—	1 (0.1)	—	—	1 (0.4)	6 (0.6)	—	3 (0.3)	—	25 (5.4)	—	—	—	13 (2.2)	—	—
Number of root canals‡																		
1 root canal	239 (99.6)§	873 (72.6)§	228 (95.0)§	865 (70.1)§	233 (97.1)§	1122 (90.2)§	206 (86.6)§	846 (77.7)§	235 (99.6)§	821 (95.7)§	10 (4.5)§	5 (1.1)§	175 (79.5)§	328 (70.8)§	39 (29.8)§	47 (8.0)§	129 (98.5)§	547 (92.9)§
2 root canals‖	1 (0.4)§	330 (27.4)	12 (5.0)§	368 (29.8)§	7 (2.9)§	122 (9.8)§	31 (13.0)§	237 (21.8)§	1 (0.4)§	34 (4.0)§	210 (95.5)	433 (93.5)	45 (20.5)§	135 (29.2)§	92 (70.2)§	529 (89.8)§	2 (1.5)§	42 (7.1)§
3 root canals¶	—	—	—	1 (0.1)	—	—	1 (0.4)	6 (0.6)	—	3 (0.3)	—§	25 (5.4)§	—	—	—§	13 (2.2)§	—	—

*Teeth presenting differences in the number of root canals between ethnic groups.

†Only lower molars with 2 independent roots.

‡Only the "number of root canals" was submitted to *z* test calculation.

§Differences between ethnic groups ($P < .05$).

‖All Vertucci configuration types with a maximum of 2 canals combined.

¶All Vertucci configuration types with maximum 3 canals combined.

previous studies. Although the highest Vertucci type I prevalence has been documented by Jing et al (40) in China (higher than any other study worldwide with 69.1% of cases), other studies from China presented a prevalence of 42.1% (41), 47.6% (42), and 48.0% (43), which are lower than previous studies in predominantly white countries such as Brazil (44) and Italy (45) (55.6% and 59.7%, respectively) but higher than other studies from Spain (11) and Brazil (46) (13.8% and 8.0%, respectively). To the authors' knowledge, the only available study comparing Asian and white ethnic groups is the study by Guo et al (4), which evaluated the morphology of the mesiobuccal roots of maxillary first molars. This study reported a higher prevalence of Vertucci types I and IV in the Asian group and a higher prevalence of Vertucci type II in whites, results that are in agreement with our findings. The present study findings for the mesiobuccal roots of maxillary first molars can be extended for the second molar also, with Jing et al (40) from China showing the highest Vertucci type I prevalence (86.1%); other studies (11, 22, 41, 43, 44, 45, 47, 48) present a mix of results.

Regarding mandibular molars, the present study confirms a significantly higher prevalence of the second distal root in the first molar and a lower number of roots in the second molar in the Asian population. This external morphology of the second molars may have a direct impact on the internal anatomy of the tooth and, in this case, on the prevalence of C-shaped morphologies, which were higher also in Asian mandibular second molars, a finding also supported by von Zuben et al (5).

As for the mandibular first molar mesial root, both ethnic groups presented a low prevalence of Vertucci type I morphologies, which is in line with the previous literature (49, 50). The most common Vertucci types for this root are Vertucci type II for whites (46.9% in the white group and 12.3% in the Asian group) and type IV for Asians (76.8% in the Asian group and 41.9% in the white group). These results are also in accordance with the previously published literature. Two Chinese studies reported a type IV prevalence in 87.7% (50) and 93.9% (51) of cases, whereas several predominantly white countries presented a lower prevalence, including Belgium (6) (16.4%), Spain (11) (37.8%), Brazil (52) (40.4%), and Italy (45) (62.4%). The same evidence is available for Vertucci type II results because Chinese studies show a prevalence of 1.7% (51) and 5.6% (50), whereas in predominantly white countries the prevalence of these morphologies was 5.0% in Belgium (6), 27.4% in Italy (45), 38.6% in Brazil (52), and 51.3% in Spain (11). The findings mentioned for the mesial root of mandibular first molars can be extended to second molars and are in agreement with the current literature (9, 11, 45, 52).

To date, it is not clear if these findings can be extrapolated to other ethnic groups. For future research, it would be interesting to perform the same comparisons between other ethnic groups to evaluate differences among other groups. As in any other prevalence study, the anatomic characteristics reported in this research are linked to the location where the data were gathered. More studies comparing the present ethnic groups are also desirable because China, being an extremely large country, may present variations within the country, and whites may also populate different countries or even continents. A comparison with ethnic groups with a similar age average would be interesting because in this study the Asian group had a 28-year-old average, whereas whites had a 51-year-old average. Few studies state that aging may influence the root canal system configuration (4, 53–55) in certain types of teeth. It is not clear the impact that this average age difference had on these 2 ethnic groups or in the Asian group in the present study, which presented in several teeth higher Vertucci type I prevalence compared with previously published Chinese studies. One of the morphologies that may change depending on the age group is the presence of an MB2 root canal (4). However, by splitting both ethnic groups in different age subgroups to perform a proper comparison with a similar age, it was possible to assess that the previously reported differences regarding the presence of MB2 root canals did not change (Table 6). In this specific clinical condition, age does not seem to be the most important factor.

In the present study, an effort was made to standardize both observers' imaging conditions. Despite the geographic distance between them, both had access to the same database for interrater reliability tests, and the local CBCT characteristics were identical, presenting both a 200-μm voxel size and large field of view. CBCT examinations with this voxel size have proved previously to be reliable and present high sensitivity values as a diagnostic tool for the detection of small root canals such as the MB2 root canal (56).

One limitation of a large CBCT sample size is the necessity to submit the patient to radiation, which we avoided by accessing already existing CBCT imaging databases in China and Portugal. As previously stated, when assessing the external validity of the study, the lack of available studies decreased the inter-research comparability.

Most of the available articles did not mention ethnic groups, and only the country's ethnicity background was taken into consideration. A limitation of the present study may be the sample size differences between the ethnic groups. However, these 2 samples (Asians: n = 3330 and whites: n = 12,325) are the largest samples documented to date analyzing the full dentition in a single study; the previous 3 available full dentition studies were from Brazil (21) (n = 1400), France (22) (n = 2424), and Georgia (28) (n = 2753). Moreover, these 2 sample sizes allow a statistical comparison between them, and the performed statistical analysis takes into account and standardizes the dimensions of both samples, thus allowing intergroup comparisons.

TABLE 6. The Presence of a Second Mesiobuccal (MB2) Root Canal in Both Maxillary Molars in Different Age Groups

		Teeth with MB2 root canal			
Group	Sample size (n)	≤20 years, n/N (%)*	21–40 years, n/N (%)	41–60 years, n/N (%)*	≥61 years, n/N (%)*
Maxillary first molar†					
Asian	238	16/32 (50.0)	112/185 (60.5)‡	11/21 (52.4)	—
White	516	8/10 (80.0)	136/192 (70.8)‡	155/214 (72.5)	69/100 (69.0)
Maxillary second molar†					
Asian	189	12/26 (46.2)	20/145 (13.8)‡	3/18 (16.7)	—
White	589	3/9 (33.3)	76/196 (38.8)‡	115/253 (45.4)	64/131 (48.9)

*Age groups not submitted to z test calculation because of small sample sizes.

†Only upper molars with at least 3 independent roots.

‡Differences between ethnic groups ($P < .05$).

Conclusions

Under the conditions of this study, it was possible to conclude that the Asian ethnic group had a lower number of roots per tooth in both maxillary premolars and mandibular canines and second molars. The white ethnic group presented a lower number of roots per tooth in both maxillary and mandibular first molars. Regarding root canal configuration, the Asian group globally demonstrated a higher tendency to present Vertucci type I configurations, showing a statistically higher prevalence in 17 of the 20 studied roots. A higher Vertucci root canal configuration variability was noted in whites. Three-root canal systems per root were more commonly found in the white group also.

When treating white patients, a clinician may expect more multiple root canal systems. This conditions does not make Asian patients easier to treat because this ethnic group has also presented a higher prevalence of mandibular second molar C-shaped morphologies and mandibular first molar 3-rooted configurations. Knowing these differences might be a clinical advantage for the clinician.

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