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Root Canal Morphology of the Mandibular First Premolars in a Yucatecan Population Using Cone Beam Computed Tomography: An *in vitro* Study

Morfología del Conducto Radicular de Primeros Premolares Mandibulares en una Población Yucateca Usando Tomografía Computarizada: Estudio *in vitro*

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SUMMARY: A successful endodontic treatment requires knowledge of the internal configuration of dental root canals. Most of the people who live in Yucatan are of Maya origin, characterized by a Mongoloid dental pattern. Because of their ethnicity, variations are expected. The purpose of this investigation is to assess the morphological characteristics and variability of this population. One hundred and five extracted first mandibular premolars of Mexican Maya population were analyzed; the sample was obtained from the Oral Surgery Clinic in the School of Dentistry at the Autonomous University of Yucatan with written informed consent. Analyses were performed by means of Cone Beam Computed Tomography. Vertucci´s Type I was the most prevalent configuration with 51.4 %, but 41 cases (39.1 %) presented a radicular groove and a C-shaped canal configuration. Overall, we documented 1, 2, 3, and 4 root canals. Mandibular first premolars are very variable in the Yucatecan population. The variability and frequency of C-shape is similar to mandibular second molars confirming the importance of the ethnic background for the endodontic treatments.

KEY WORDS: C-shaped canal; Mandibular first premolar; Root canal morphology.

INTRODUCTION

The success of root canal treatment depends on the ability to make a thorough cleaning, shaping, and sealing. Thus, knowledge about root canal morphology is essential (Hargreaves & Berman, 2016). However, many different variants in root canal morphology have been reported in populations including C-shape, extra roots, and fusion configurations. These can be characterized with tomography. The aim of this analysis is to assess the characteristics and the extent of variability of the root canal morphology in the Maya population from this region.

MATERIAL AND METHOD

The teeth were collected from patients who required extraction in the Oral Surgery Clinic at the School of Dentistry of at the Autonomous University of Yucatan (UADY) (Merida, Mexico). The reasons for extractions were totally independent of this study. The Medical Ethics Committee of the UADY approved this study. Written informed consent was obtained from all patients, and a questionnaire was completed to report sex, age, and ethnic origin. One hundred and five teeth (according to sample size Epi Info) were obtained, which fulfilled the following criteria: 1. Signed consent. 2. Have at least one Maya last name and be born in Yucatan with parents and grandparents of Maya ethnicity. 3. Presence of a complete permanent mandibular first premolar. 4. Absence of root canal treatment, caries or restoration, root resorption or periapical lesions.

The teeth were cleaned of any soft-tissue remnants, disinfected with 2.5 % sodium hypochlorite and an ultrasonic bath (NSK Varios 560 ® Japan). They were individually identified with a folio number and stored in an individual bag.

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The Cone Beam Computed Tomography (CBCT) images were obtained using a CBCT scanner (Kodak Carestream 9000 3D ® Spain) at 85 kV and 35.0 mA with an exposure time of 40 seconds, a voxel size of 200 mm, a slice thickness of 2.0 mm and coupled to a Kodak Carestream 9000 3D ® (Spain) software. The acquisition process was performed by an experienced radiologist according to the manufacturer's recommended protocol with the minimum exposure necessary for adequate image quality. The number of roots and root canals were determined in each tooth by moving the cursor to the Z-axis. The root canal configurations were assigned according to Vertucci's classification (Vertucci, 1984). Fan *et al*. (2008) categorization of the mandibular first premolars was used as reference for the C-shaped canal configurations. The qualitative and quantitative features that characterized the root and root canals were observed and recorded. These were reported in an Excel ® database, and the frequencies and statistical analyses were calculated (Statistica 7.0 StatSoft Ò).

RESULTS

The macroscopic analysis indicated 102 teeth with one root (97.1 %) and 3 with two roots (2.9 %). The CBCT study showed 54 teeth (51.4 %) with one canal; 35 (34.3 %) had two canals, ten (9.8 %) had three canals, and the remaining three (2.9 %) had four canals. All 54 teeth with one canal were Vertucci´s Type I (Vertucci). Of the 35 cases with two canals, 13 (37.1 %) corresponded to Type III, 19 (54.3 %) to Type V, two cases were Type VII (5.7 %) and one had a 12121 (2.9 %) pattern. Of the 13 remaining cases that presented three or four canals, two showed a 1-2-3 pattern, three a 1-2-3-1 pattern, three a 1-2-3-2-1 pattern and the remaining had 1-3, 1-2-3-2, 1-2-4-2, 1-2-3-2-4, and 1-2-3-2-3-4 canal patterns detected in one tooth each. As regards the three cases with 2 roots, two presented a mesial (Type V) and distal (One Type I and one Type V) root position; and one had one buccal root with a canal Type II and a Type I lingual root (Table I).

C-shaped configuration. An external groove was observed in 41 cases (39.1 %)— 37 on the mesiolingual side (90.2 %), three on the distolingual side (7.3 %) and one on the lingual side (2.4 %). All 41 cases (100.0 %) had a C-shaped root canal, none of which started at the cervical radicular portion. In three cases (7.3 %), the C-shape started at 2/3 of the root; 18 teeth (43.9 %) showed a C-shape starting at about 1/2 height of the root, 17 (41.5 %) had a C-shaped canal starting at 1/3 of the root length and three specimens (7.3 %) started at 2.5 mm from the apical end. The distribution of the C-shaped canals according to Vertucci´s classification is shown in Table I, and the internal classification based on Fan *et al*. (2008) is in Table II.

Table I. Root canal morphology of the mandibular first premolar according to Vertucci´s classification and presence of C-shaped configuration.

Type of canal	Canal pattern	N	%	C-shaped	%
I	11	54	51.4	4	7.4
III	121	13	12.4	11	84.6
V	12	19	18.1	12	63.2
VII	1212	2	1.9	2	100.0
Additional type	12121	1	1.0	0	0.0
	13	1	1.0	1	100.0
	123	2	1.9	2	100.0
	1231	3	2.9	2	66.7
	1232	1	1.0	1	100.0
	12321	3	2.9	3	100.0
	1242	1	1.0	1	100.0
	12324	1	1.0	1	100.0
	123234	1	1.0	1	100.0
2 ROOTS		3	2.9	0	0.0
TOTAL		105	100.0	41	39.1

Table II. Root canal distribution of C-shape according to Fan´s *et al*. classification in mandibular first premolars.

	C1	C2	C3	C4a	C4 C4b	C4c	C5	C6
cej	0	0	0	1	2	38	0	0
2/3 rad	1	0	4	2	1	33	0	0
1/2 rad	6	1	20	0	1	13	0	0
1/3 rad	8	0	31	0	0	2	0	0
at 2.5 mm apical	3	1	33	1	0	3	0	0
at 1 mm apical	1	0	21	2	0	16	1	0

Distribution of canal morphology by sex (Table III) indicates that both males and females present about 50 % of Type I, and difference is not statistically significant (Chi-square = .046, 1 d.f., p=.83). Also the distribution of the remaining root morphology types (excluding Vertucci's Type I) does not reach the .05 thresholds (Chi-square 2.16, 3 d.f., p=.54), despite females show higher frequencies of Type III. In terms of side (Table IV), the right one shows 31 % Type I canals, vs 59.2 % in the left side. Difference by side is statistically significant at the .05 thresholds (Chi-square = 6.67, 1 d.f., p=.0097). Also distribution of non-Type I canals presents differences between left and right teeth, but it is not statistically significant (Chi-square = 7.443, 3 d.f., p= .077).

Table III. Root canal distribution between males and females.

Sex	Type	N	%	C-shaped	%
MALES	I	18	52.9	2	11.1
	III	2	5.9	2	100.0
	V	7	20.6	4	57.1
	VII	1	2.9	1	100.0
	IX	4	11.8	4	100.0
	2 ROOTS	2	5.9	0	0.0
	TOTAL	34	100.0	13	38.2
	Type	N	%	C-shaped	%
FEMALES	I	36	50.7	2	5.6
	III	11	15.5	9	81.8
	V	12	16.9	8	66.7
	VII	1	1.4	1	100.0
	Aditional types	10	14.1	8	80.0
	2 ROOTS	1	1.4	0	0.0
	TOTAL	71	100.0	28	39.4

Table IV. Root canal distribution between right and left side.

Side	Type	N	%	C-shaped	%
RIGTH	I	9	31.0	2	22.2
	III	2	6.9	1	50.0
	V	10	34.5	7	70.0
	VII	0	0.0	0	0.0
	Aditional types	8	27.6	7	87.5
	2 roots	0	0.0	0	0.0
	TOTAL	29	100.0	17	58.6
	Type	N	%	C-shaped	%
LEFT	I	45	59.2	2	4.4
	III	11	14.5	10	90.9
	V	9	11.8	5	55.6
	VII	2	2.6	2	100.0
	Aditional types	6	7.9	5	83.3
	2 roots	3	3.9	0	0.0
	TOTAL	76	100.0	24	31.6

DISCUSSION

Several studies have focused on root and root canal morphology (Gu *et al*., 2013a; Singh & Pawar, 2014; Sun *et al*., 2016; Cucina & Navarro, 2016; Martins *et al*., 2017), but most did not consider the ethnic/genetic origin of the population. Root type and root canal morphology depend on the population's ethnicity, and it is critical to consider this feature for better root canal treatment (Trope *et al*., 1986).

The modern Maya population in the Yucatecan region (i.e., excluding the modern immigrants from foreign countries as well as from other states in Mexico) have a Mongoloid dental structure, but received Caucasoid and African influence during the last five centuries due to colonization (Cucina & Navarro). While the majority of the traits have retained their original Mongoloid frequency of expression (Ramírez-Salomón *et al*., 2014; Cucina & Navarro), others have changed as a response to such recent genetic admixture (Cucina & Navarro).

In contrast to the majority of papers in the literature, the sample studied here is ethnically controlled—all teeth were from patients of known origin, sex, and age. The results indicate that 97.1 % of the first mandibular premolars have one root, and 2.9 % were two-rooted. Such a distribution agrees with the literature from different populations worldwide, which shows that two-rooted mandibular first premolars are rare (Table II). Indeed, most populations have a frequency of single rooted premolars close to 100.0 %; only few are near 95.0 %.

Only Trope *et al*. reported frequencies of two-rooted mandibular first premolars that exceed those reported in all the other studies: 16.2 % in an Afro-American sample. From an anthropological perspective, Scott & Turner (1997) consider the two-rooted mandibular first premolar as Tomes' root. They state that the populations with higher occurrences worldwide are the Sub-Saharan Africans reaching a frequency as high as 38.0 %. This trait is common in Africans and Australian people. However, Tomes' root is reported as a trait characterized by varying degrees of expression in grooved roots. Only the maximum expression is a two-rooted tooth, according to Scott and Turner's standardized system. However, the frequencies they report also include a deep groove that runs continuously on both the mesial and distal surfaces of the root without creating two physically separated roots. Therefore, the frequencies

Table V. Number of roots in the mandibular first premolar worldwide.

Author	Group	Country	Sample size	Frequency %		
				One root	Two roots	Three roots
Vertucci (1984)	North Americans	USA	400	100.0	0.0	0.0
Trope *et al.* (1986)	Euro-Americans	USA	400	94.5	5.5	0.0
Trope *et al.* (1986)	Afro-Americans	USA	400	83.8	16.2	0.0
Esponda (1994)	Latin-Americans	Mexico	-	>95.0	-	0.0
Sert and Bayirli (2004)	Caucasoids	Turkey	200	100.0	0.0	0.0
Greco-Machado *et al.* (2009)	Europeans	Spain	50	100.0	0.0	0.0
Khedmat *et al.* (2010)	Caucasoids	Iran	217	100.0	0.0	0.0
Fan *et al.* (2012)	Asian	China	327	100.0	0.0	0.0
Yang *et al.* (2013)	Asian	China	440	99.3	0.7	0.0
Singh and Pawar (2014)	South Asian Indian	India	100	94.0	6.0	0.0
Martins *et al. (*2017)	Caucasoids	Portugal	1123	99.8	0.2	0.0
Pedemonte *et al.* (2017)	South - Americans	Chilean	101	94.0	6.0	0.0
Pedemonte *et al.* (2017)	Caucasoids	Belgian	100	100.0	0.0	0.0

reported by Scott & Turner clearly overestimate the real frequency of two-rooted mandibular first premolars. Nonetheless, we can still infer that two-rooted mandibular first premolars are more frequent in these two populations, which largely confirms the values reported for Afro-Americans by Trope *et al*.

The evolutionary characteristic of the mandibular first premolar is single-rooted in most human populations. The frequency of 97.1 % in the modern Yucatecan sample is consistent with this evolutionary process and with the (potential) European genetic influence. The frequencies are similar to populations in northeastern Asia (Table V). In contrast, the influence of African people is not sufficiently strong to affect the morphological structure of the tooth. This frequency concurs with Esponda (1994) who encountered more than 95.0 % single rooted mandibular first premolars in a Mexican population and whose genetic history is very similar to that of the sample under study.

With regards to root canal configuration, all previous studies report that the most common feature in mandibular first premolars is one root canal (Vertucci's Type I). As our results also indicate, this aspect is not related to the sex of the individual; however, the comparison between left and right sides indicate a significant prevalence of Type I in the former. Despite sample size can be a factor in this difference, further analyses and larger comparative samples are necessary.

In general, the frequencies of Type I are very variable worldwide, ranging from 53.7 % to 88.5 % (Vertucci; Trope *et al*.; Sert & Bayirli, 2004; Lu *et al*., 2006; Greco-Machado *et al*., 2009; Liu *et al*., 2013; Yang *et al*., 2013; Singh & Pawar; Chen *et al*., 2014; Sun *et al*.; Martins *et al*.; Pedemonte *et al*., 2017). Caucasoid (European) populations had the highest frequencies (Trope *et al*.; Khedmat *et al*., 2010; Pedemonte *et al*.), and Asian populations had the lowest (Liu *et al*.; Sun *et al*.). This study shows that the Yucatecan population falls well within the range of variability of Asian populations—51.4 % were Vertucci's Type I. This also indicates that the Asian populations (including the Yucatecan one) are characterized by a higher degree of variability in terms of internal root canals' morphology.

The results indicate that Vertucci's Type V was the second most frequent morphology (18.1 %) similar to other studies that presented frequencies of 9.3 % to 25.6 % (Vertucci; Lu *et al*.; Greco-Machado *et al*., 2009; Liu *et al*.; Yang *et al*.; Chen *et al*.; Sun *et al*.; Martins *et al*.; Pedemonte *et al*.). Only Singh & Pawar and Sert & Bayirli reported second higher frequencies of Type IV (10.0 %) and Type II (18.5 %) in patients from India and Turkey, respectively. Based on this variability and on the frequencies of root canals not corresponding to Type I, it is clearly important to understand the ethnic origin of the patient.

This investigation shows that the modern Maya population has higher frequencies of C-shape in the mandibular first premolars (39.1 %) in comparison with the values reported in the literature, which range between 1.1 % (Yang *et al*) and 29.7% (Fan *et al*. 2012). Yang *et al*. reported a 1.1 % frequency in a Chinese population—these low values are common in Caucasian populations. The high frequencies seen in the literature were also seen in Asian populations (Lu *et al*.; Fan *et al*., 2008; Khedmat *et al*.; Fan *et al*., 2012; Yang *et al*.; Gu *et al*., 2013a,b). The C-shape pattern in premolars concurs with the same morphology recorded in the mandibular second molars, which showed frequencies above 30 % in Prehispanic and modern Maya (Ramírez-Salomón *et al*. 2014), Chinese (Zheng *et al*., 2011), and Korean (Jin *et al*. 2006) populations: 35.0 % in Maya and Yucatecans, 38.6 % in Chinese, and 44.6 % among Koreans.

Most of the literature on the mandibular first premolars reports one canal in the root's cervical portion, while the C-ribbon is located in the medial and apical thirds of the root (Fan *et al*., 2008; Khedmat *et al*.; Fan *et al*., 2012; Gu *et al*., 2013a,b; Liu *et al*.; Ordinola-Zapata *et al*., 2015). This pattern is different from mandibular second molars in which the C-ribbon can already be observed in the root's cervical third (Hargreaves & Berman).

The mandibular premolars' C-ribbon pattern—in which the C-shape cannot be appreciated in the root's cervical portion—makes its identification and endodontic intervention more difficult. It somewhat decreases the success of treatment—especially in the presence of chronic pathological conditions. Higher frequencies of C3 canals were found in Asian populations (Lu *et al*.; Fan *et al*., 2008) except for C1 and C2 types reported by Gu *et al*. (2013a,b). Khedmat *et al*. described a Caucasian population from Iran and reported that C3 is the most common type, while an analysis of a Brazilian population indicated the C1 and C2 types in the medial and apical thirds of the roots are the most common (Ordinola-Zapata *et al*.).

European populations have a groove along the premolars' roots whose frequencies range between 1.4 % (Khedmat *et al*.) and 10.9 % (Martins *et al*.). Such frequencies instead range between 24.0 % (Fan *et al*. 2008) and 56.2 % (Gu *et al*. 2013a) in Asiatic populations. Again, the frequencies in Asian groups are consistent with the results of our study. Several papers report that 100.0 % of the C-ribbon was found in mandibular first premolars with groove, indicating a correlation between the presence of the groove and the C-ribbon similar to our findings (Lu *et al*.; Fan *et al*., 2008; Khedmat *et al*.; Fan *et al*., 2012). The exceptions to this pattern were the studies by Fan *et al*. (2012), Ordinola-Zapata *et al*. and Martins *et al*., who reported C-shape ribbon respectively in 66.2 %, 67.5 %, and 21.3 % of the teeth with an external groove. The location of the groove in the Yucatecan population was mesiolingual, which is consistent with the evidence found in other studies (Fan *et al*., 2008; Gu *et al*., 2013a; Liu *et al*.; Martins *et al*.); nonetheless, lingual and mesial main positions were reported by Lu *et al*. and Chen *et al*. respectively.

CONCLUSION

Overall, half of the sample presented one root canal along the whole length of the root; the other half was very variable. Most variations in first mandibular premolar in this Maya population had a C-shaped configuration, had more than one root canal, and were located from the middle to the apical portion of the root.

The ethnic origin of the Yucatecan population is Sino-American from northeastern Asia. The C-shaped first premolar is very common in this group; our results confirm the similarities with the Asian populations and agree with the endodontic and anthropological literature. Knowledge of root canal configuration is a basic requirement for practitioners for a successful endodontic treatment. Whereas available, computed tomography should be used in all cases when needed. Further studies should analyze more detailed measures, and the C-shaped configurations in diverse populations should be analyzed according to ethnic background.

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RESUMEN: El éxito en el tratamiento endodóntico requiere el conocimiento profundo de la configuración interna del sistema de conductos radiculares. La mayoría de las personas que viven en Yucatán son de origen Maya y poseen el patron dental Mongoloide; por lo tanto, se esperan variaciones debido a su etnicidad. El propósito de esta investigación fue evaluar las características morfológicas y la variabilidad del conducto radicular en la población yucateca. Se analizaron ciento cinco primeros premolars mandibulares extraídos de pacientes provenientes de una muestra Maya mexicana; la muestra fue obtenida de la Clínica de Cirugía Oral de la Facultad de Odontología de la Universidad Autónoma de Yucatán. Con consentimiendo informado escrito. Se utilizaron Tomografías Computarizadas para el análisis de la muestra. La configuración más prevalente fue la Tipo I de Vertucci con 51,4 %. Sin embargo, 41 de 105 casos (39,1 %) presentaron un surco radicular y la configuración en forma de "C". Se documen-

taron casos con 1, 2, 3 y 4 conductos radiculares. Los primeros premolares mandibulares de la población Yucateca son muy variables. La variabilidad y frecuencia de conductos en forma de "C" concuerda con estudios realizados en segundos molars mandibulares en esta zona confirmando la importancia del origen étnico de las poblaciones para los tratamientos endodónticos.

KEY WORDS: Conducto en forma de "C"; Primeros premolars mandibulares; Conducto radicular.

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