Int. J. Morphol.,
40(3):573-578, 2022.

Anatomical and Morphological Findings of the Root Canal of Maxillary Premolars and Their Prevalence: CBCT Study in a Mexican Population

Hallazgos Anatómicos y Morfológicos del Conducto Radicular de Premolares Maxilares y su Prevalencia: Estudio CBCT en una Población Mexicana

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MEDINA, G. C. A.; OLIVA, R. R.; CALVILLO, M. D. H.; MARIEL, C. J.; MUÑOZ, R. A. I. & GUTIÉRREZ, C. F. J. Anatomical and morphological findings of the root canal of maxillary premolars and their prevalence: CBCT study in a Mexican population. *Int. J. Morphol., 40(3)*:573-578, 2022.

SUMMARY: An essential prerequisite to perform any dental procedure is a clear understanding and knowledge of dental anatomy and its possible variations. The root canal system is characterized for a complex morphology, which varies among populations, i ndividuals in the same population and even in the same person. The aim of this study was to evaluate by CBCT the morphology, number, curvature, and length of roots of first and second maxillary premolars in a Mexican population. In this stud 1700 maxillary premolars were evaluated by CBCT scans of patients; the axial, sagittal and coronal sections were analyzed following the longitudinal axis of each tooth. As a result 51.60 % of the maxillary first premolars had a single root, 31.03 % had two roots, 16.29 % had root fusion, and 1.07 % had three roots. 22.3 % of the maxillary first premolars showed mesial curvature, 41.9 % had a distal curvature, and 35.7 % did not show any curvature; and the most prevalent configuration in maxillary first premolars was Type V. 88.9 % of the maxillary second premolars had a single root, 3.9 % had two roots, 6.9 % had root fusion, and 0.11 % had three roots; 37.59 % of the maxillary second premolars showed a mesial curvature and 62.40 % showed a distal curvature; and the most prevalent configuration in maxillary second premolars was Type I. The anatomy of the root canal system is extremely complex and has many anatomical configurations, these clinical situations must be considered previous to performing any endodontic treatment.

KEY WORDS: Root Canal System; Anatomy; CBCT.

INTRODUCTION

An essential prerequisite to perform any dental procedure is a clear understanding and knowledge of dental anatomy and its possible variations, especially in the case of root canal related treatments (Kottoor, *et al*., 2013; Ahmed, *et al*., 2017; Wu *et al*., 2020). The long-term success of the endodontic treatment is related with different factors, such as shaping, cleaning and tridimensional sealing of the root canal system (RCS) (Razumova *et al*., 2020), all these factors are adversely influenced by the highly variable anatomy/ morphology of the RCS (Peters, 2004; Bansal *et al*., 2018; Razumova *et al*., 2020). Since the presence of an untreated canal may be a reason for treatment failure. It is extremely important that clinicians use all the available resources to locate and treat the entire RCS, also, it has been stablished that diagnosis, treatment planning, knowledge of the canal morphology and its frequent variations is a basic requirement for endodontic success (Vertucci, 2005).

As previously mentioned, the RCS is characterized for a complex morphology, which varies among populations, individuals and even in the same person (Ahmed *et al*., 2017; Razumova *et al*., 2020). The RCS may divide, rejoin, and have additional canals and a variety of configurations (Kottoor *et al*., 2013). Different techniques have been

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Received: 2022-03-24 Accepted: 2022-04-18

previously employed to study and analyze RCS morphology, such as transparent tooth staining procedures, serial sections of isolated teeth (Estrela *et al*., 2015; Wu *et al*., 2020), microscopic analysis (Estrela *et al*., 2015), clinical radiograph techniques (Estrela *et al*., 2015; Vertucci, 2005), among others. More recently, cone-beam computed tomography (CBCT) has been introduced as a tool for evaluation of morphology (Peters, 2004; Razumova *et al*., 2020; Wu *et al*., 2020) and endodontic research, becoming an invaluable, non-destructive technique for examining the shape and morphology of the RCS (Cheung *et al*., 2007).

Knowledge of the morphology and the most common variants of the RCS contributes to the knowledge, research, and clinical practice in endodontics, also it is important to highlight the fact that it is necessary to perform a morphology study and analysis in each population due to known variations. The objective of the study was to evaluate by CBCT the morphology, number, curvature, and length of roots of first and second maxillary premolars in a Mexican population.

MATERIAL AND METHOD

This work was authorized by the Research Ethics Committee of the Faculty of Stomatology, UASLP, Mexico (CEI-FE-006-020).

In the present study we evaluated 700 CBCT scans [voxel size of .76 mm] [field of view 15x15 mm] (obtained with the New Tom VGI 3D Cone Beam) of patients of the Radiology Clinic of the Faculty of Stomatology, UASLP, Mexico. All images were evaluated with Horos software (version 3.3.5). The inclusion criteria for the study were: CBCT images of healthy maxillary first premolars (MFP) and maxillary secondpremolars (MSP) with complete root formation; the exclusion criteria were premolars with immature apices, root canal treatment, restorations, or root resorption; the elimination criteria include non-assessable CBCT images or with premolars absents.

The axial, sagittal and coronal sections were analyzed following the longitudinal axis of each tooth, taking as reference three basic measurement planes located in the cervical, middle, and apical areas of each maxillary premolar. To observe the presence of the RCS, transverse root cuts were done. The number of roots, tooth length and root length, as well as the root curvature, anatomical configuration, number of root canals and morphology were evaluated according to Vertucci's classification (Vertucci & Gegauff, 1979).

For the referential sections for the topographic analysis measurements of the upper premolars, reference lines were drawn, Line A: following the course of the cement-enamel union; Line B: perpendicular to Line A, then the three planes were established as follows: Cervical (3 mm in the direction from the cement-enamel junction towards apical); Middle (Half of the distance between the cement-enamel junction and the radiographic apex); Apical (3 mm in the direction from the radiographic apex towards the cement-enamel junction).

The obtained data were exported to PASW Statistics 18 software. Then the descriptive statistics were carried out, frequency tables and measures of central tendency were obtained. To evaluate the association between sex and the variables, Pearson's Chi-square statistical test was employed and to compare the root length of the tooth between female and male patients, the student's T statistical test was used. For all these tests a confidence level of 95 % was considered.

RESULTS

From the 700 CBCT scans observed, 180 CBCT images were determined to be uninterpretable, and 287 premolars were absent. A total amount of 2153 maxillary premolars were evaluated, of which 42 had endodontic treatment or restoration, 6 showed root resorption and 405 showed immature apices. Finally, 1700 maxillary premolars were included in the study, of which 841 were first premolars and 859 second premolars.

Maxillary First Premolars

Tooth Length and Root Length. 841 MFP were evaluated; 545 belonged to female patients, with a mean tooth length of 19.061 mm and a root length mean of 12.084 mm; 296 belonged to male patients, with a mean tooth length of 18.905 mm and a root length mean of 12.283 mm (Table I). No statistical significant differences were found between sex, tooth length and root length (P>0.05).

Table I. Tooth length according to sex in first maxillary premolars.

	Sex	n	Mean	Standard Deviation	P
Tooth length	Man	296	18.905	0.21	0.284
	Woman	545	19.061	0.20	
Root length	Man	296	12.283	0.19	0.124
	Woman	545	12.084	0.17	

Number of Roots. 48.45 % of the total MFP analyzed had a single root, 33.9 % had two roots, 16.20 % had root fusion, and 1.45 % had three roots.

48.3 % MFP of female patients showed a single root, 34.7 % showed two roots, 16.8 % had root fusion and 0.20 % showed three roots. In comparison, 48.6 % of male patients showed one root, 33.1 % had two roots, 15.5 % showed root fusion and 2.70 % had three roots (Table II). According to Pearson's Chi square a significant difference were found with respect to sex and the number of roots in MFP (p=0.009).

Table II. Number of roots in first premolars.

Sex	One Root	Two Roots	Three Roots	Root Fusion
Man	48.60%	33.10%	2.70%	15.60%
Woman	48.30%	34.70%	0.20%	16.80%
Total	48.45%	33.90%	1.45%	16.20%

Root Curvature. 540 MFP showed a curvature; 21.65 % showed mesial curvature, 42.20 % showed distal curvature, and 36.15 % did not show any curvature (Table III). According to Pearson's Chi-square no significant differences were found with respect to sex and root curvature (P=0.481).

Table III. Root curvature in first maxillary premolars.

Sex	Mesial Root Curvature	Distal Root Curvature	Straight Root
Man	19.60 %	43.20 %	37.20 %
Woman	23.70 %	41.20 %	35.10 %
Total	21.65 %	42.20 %	36.15 %

RCS Configuration. The most common configuration in MFP were Type V with a 31.74 % (n=267), 20.33 % showed a Type I configuration (n=171), 17.24 % showed a Type IV configuration (n=145), 14.86 % showed a Type III configuration (n=125), 13.43 % showed a Type II configuration (n=113), and 0.35 % showed a Type VI configuration (n=3) (Table IV).

Maxillary Second Premolars

Tooth Length and Root Length. 859 MSP were evaluated; 550 belonged to female patients, with a mean tooth length of 18.69 mm and a root length mean of 11.86 mm were obtained; 309 belonged to male patients, with a mean tooth length of 18.60 mm and a root length mean of 12.14 mm (Table V). No statistical significant differences were found between sex, tooth length and root length (P>0.05).

Number of Roots. 88.9 % of the MSP analyzed had a single root, 3.9 % had two roots, 6.9 % had root fusion, and 0.11 % had three roots.

Table V. Tooth length according in second maxillary premolars.

	Sex	n	Mean	Standard Deviation	P
Tooth length	Man	309	18.6	0.2	0.504
	Woman	550	18.69	0.2	
Root length	Man	309	12.14	0.17	0.058
	Woman	550	11.86	0.18	

86 % MSP of female patients showed a single root, 6.4 % showed two roots, and 7.6 % had root fusion. In comparison, 90.6 % of male patients shown one root, 2.9 % had two roots, 5.8 % shown root fusion and 0.7 % had three roots (Table VI). According to Pearson's Chi square a significant difference were found with respect to sex and the number of roots in MFP (P=0.0310).

Root Curvature. 556 MSP showed a curvature, of which 23.7 % showed a mesial curvature, 41.6 % showed a distal curvature and 34.7 show a straight root (Table VII).

Table VI. Number of roots in second premolars.

One Root	Two Roots	Three Root	Root Fusion
90.60 %	2.90 %	0.70 %	5.80 %
86.00 %	6.40 %	0	7.60 %
88.30 %	4.65 %	0.35 %	6.70 %

According to Pearson's Chi-square no significant differences were found with respect to sex and root curvature (P=0.179).

RCS Configuration. The most common configuration in MFP were Type I with a 74.62 % (n=641), 8.8 % shown a Type III configuration (n=76), 8.1 % shown a Type V configuration (n=70), 4.42 % shown a Type II configuration (n=38), and 3.60 % shown a Type IV configuration (n=31) (Table VIII).

Table VII. Root curvature in second maxillary premolars.

Sex	Mesial Root curvature	Distal Root Curvature	Straight Root
Man	22.70 %	44.80 %	32.50 %
Woman	24.70 %	38.40 %	36.90 %
Total	23.70 %	41.60 %	34.70 %

Table IV. Configuration of the root canal system according in first maxillary premolars.

s		I	II	III	IV	V	VI	VII	VIII	Variant A	Variant B	Total
Man	n	70	36	39	53	86	0	0	1	3	8	296
	Percentage	23.60 %	12.20 %	13.10 %	17.90 %	29.10 %	0	0	0.30 %	1.00 %	2.70 %	35.19 %
Woman	n	101	77	86	92	181	3	0	0	4	1	545
	Percentage	18.40 %	14.20 %	15.80 %	16.90 %	33.30 %	0.60 %	0	0	0.70 %	0.20 %	64.80 %
Total	n	171	113	125	145	267	3	0	1	7	9	841
	Percentage	20.33 %	13.43 %	14.86 %	17.24 %	31.74 %	0.35 %	0	0.11 %	0.83 %	1.07 %	100 %

Table VIII. Configuration of the root canal System in second maxillary premolars.

Sex		I	II	III	IV	V	VI	VII	VIII	Variant A	Variant B	Total
Man	n	241	8	33	11	13	0	0	0	2	1	309
	Percentage	78.20 %	2.60 %	10.60 %	3.60 %	4.20 %	0	0	0	0.60 %	0.32 %	35.97 %
Woman	n	400	30	43	20	57	0	0	0	0	0	550
	Percentage	86.56 %	6.40 %	7.60 %	2.32 %	6.63 %	0	0	0	0	0	64.02 %
Total	n	641	38	76	31	70	0	0	0	2	1	859
	Percentage	74.62 %	4.42 %	8.80 %	3.60 %	8.10 %	0	0	0	0.20 %	0.10 %	100 %

Anatomical variantions.

Two morphological variants that do not belong to the Vertucci's classification were observed in the study. Variant A (2-3-2) start with two canals in the pulp chamber, during its course a canal bifurcates into two and again joins in one; Variant B (2-3-3) start with two canals in the pulp chamber, during its course one of them bifurcates in two toward the apex. In MFP 0.83 % shows a Type A variant configuration, and 1.07 % shows a Type B variant configuration; In MSP 0.1 % shows a Type A variant configuration, and 0.2 % shown a Type B variant configuration (n=2).

DISCUSSION

In the present study the anatomy and morphology of the RCS of maxillary first and second premolars in a Mexican population were evaluated and analyzed.

Negligence, lack of planning and knowledge of internal anatomy contributes significantly to the difficulties during the RCS treatment (Estrela *et al*., 2015). Understanding of RCS morphology and possible variations is an essential prerequisite (Wu *et al*., 2020) to perform an adequate therapeutic technique (Razumova *et al*., 2020), and reduce failure of endodontic treatment (Wu *et al*., 2020).

Anatomical variations can occur in any tooth (Estrela *et al*., 2015), there is a high percentage of canal irregularities, such as accessory or lateral canals, and apical delta, suggesting that the cleaning, shaping and filling of the RCS would be a challenge for any clinician (Cheung *et al*., 2007). Clinical implications of knowledge of RCS anatomy have been related with the successful treatment obtaining full access to internal areas during the cleaning and RCS filling process (Estrela *et al*., 2015).

The anatomic structures of human teeth (number of roots, root canals, apical foramina, root canal isthmuses, root ramifications, root curvatures, developmental disturbances) have been evaluated by destructive and non-destructive methodologies (Estrela *et al*., 2015; Wu *et al*., 2020). The methods described in the literature include decalcification, radiography, vertical and cross-sectional cutting, histological evaluation, stereomicroscopy analysis, surgical microscopy, plastic casts, scanning electronic microscopy, cone beam computed tomography (CBCT) and micro-computed tomography (Estrela *et al*., 2015). Among the different anatomy classification systems, Vertucci's classification (Vertucci & Gegauff, 1979) is used widely to study RCS morphology, the main advantage of this classification is that it covers most of the different anatomic configurations, nevertheless, since the RCS morphology is highly variable there are some variations not considered.

The populations around the world have some peculiarities that must be respected. Anatomical variations are identified in the literature (Estrela *et al*., 2015), but there are some populations in which there is not enough information related with the anatomical dental morphology, in the present study the most common anatomical characteristics and some variations of MFP and MSP in a Mexican population were determined.

In the study of Wu *et al*. (2020), performed in Chinese population by CBCT, was reported that most of the maxillary first premolars had 1 root (67.4 %), followed by 2 roots (32 %). Being the two-canal configuration (89 %) the most prevalent. For mandibular first premolars, 98.8 % had 1 root and 81 % presented the type I configuration. Also it was reported that there were no statistical differences in the number of roots or morphology in terms of sex; in another study, reported by Senan *et al*. (2018) and performed in MFP in Yemeni population, reported that 54.8 % of teeth were single-rooted, while 44.4 % were double-rooted and only 0.8 % had three separated roots. The most common configuration was Vertucci type IV (55.6 %). Eight specimens of the single-rooted premolars (3.2 %) had new

canal configurations that have not been recognized in previous published studies; in a study reported by Estrela *et al*. (2015) and done by CBCT, was identified that maxillary first and second premolars had two roots in 66 % and 17 % of the cases, respectively, and one root in 32 % and 83 % of the cases, respectively. As much as 88 % of maxillary first premolars and 73 % of maxillary second premolars had two root canals. Finally, six percent of maxillary first premolars presented three root canals. The differences in the number and configuration of root canals of maxillary premolars evaluated in this study in comparison with previous reported literature. The above could be due to different evaluation CBCT axial planes and method, but mainly to the evaluated population being different in each study, as previously mentioned the morphology and configuration could differ depending on the evaluated group.

There are differences when comparing previous reported literature (Vertucci & Gegauff, 1979; Pécora *et al*., 1992; Kartal *et al*., 1998) in which other methods of evaluation were used, like radiographs, clearing and staining. The evaluation method in the present study was CBCT, which has been shown to be a useful method to perform a clinical evaluation of the tridimensional configuration of anatomical structures and offer advantages, when comparing with conventional techniques (Serhal *et al*., 2000; Asaumi *et al*., 2010; Rocha-Castillo *et al*., 2019).

CONCLUSION

The anatomy of the RCS is extremely complex and has many anatomical configurations, these clinical situations must be considered previous to performing any treatment related with the RCS. Also, each patient must be carefully evaluated, and must consider the anatomic, ethnic, and genetic features that could influence the treatment must be considered. Finally, the navigation by CBCT has been shown to be a precise tool to identify and predict the position of root canals in patients.

MEDINA, G. C. A.; OLIVA, R. R.; CALVILLO, M. D. H.; MARIEL, C. J.; MUÑOZ, R. A. I. & GUTIÉRREZ, C. F. J. Hallazgos anatómicos y morfológicos del canal radicular de premolares maxilares y su prevalencia: estudio CBCT en una población mexicana. *Int. J. Morphol., 40(3)*:573-578, 2022.

RESUMEN: Un requisito esencial previo a la realización de cualquier procedimiento dental es una clara comprensión y conocimiento de la anatomía dental y sus posibles variaciones. El sistema de canales radiculares se caracteriza por una morfología compleja, que varía entre poblaciones, individuos en una misma población e incluso en una misma persona. El objetivo de este estudio fue evaluar mediante CBCT la morfología, número, curvatura y longitud de raíces de primeros y segundos premolares maxilares en una población mexicana. En este estudio se evaluaron 1700 premolares maxilares mediante escaneos CBCT de pacientes; se analizaron los cortes axial, sagital y coronal siguiendo el eje longitudinal de cada diente. El 51,60 % de los primeros premolares maxilares tenían una sola raíz, el 31,03 % tenían dos raíces, el 16,29 % tenían fusión de raíces y el 1,07 % tenían tres raíces. El 22,3 % de los primeros premolares maxilares presentaban curvatura mesial, el 41,9 % presentaban curvatura distal y el 35,7 % no presentaban curvatura alguna; y la configuración más prevalente en primeros premolares maxilares fue el Tipo V. El 88,9 % de los segundos premolares maxilares tenían una sola raíz, el 3,9 % dos raíces, el 6,9 % fusión de raíces y el 0,11 % tres raíces; El 37,59 % de los segundos premolares maxilares presentaban curvatura mesial y el 62,40 % curvatura distal y la configuración más prevalente en segundos premolares maxilares fue el Tipo I. La anatomía del sistema de canales radiculares es extremadamente compleja y tiene muchas configuraciones anatómicas, estas situaciones clínicas deben ser consideradas antes de realizar cualquier tratamiento de endodoncia.

PALABRAS CLAVE: Canal radicular; Anatomía; CBCT.

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