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Root Anatomy and Canal Configuration of Maxillary Premolars: A Cone-beam Computed Tomography Study

Anatomía de la Raíz y Configuración del Conducto de los Premolares Maxilares: Estudio de Tomografía Computarizada de Haz Cónico

Monardes, H.[1]; Herrera, K.[1]; Vargas, J.[1]; Steinfort, K.[1]; Zaror, C.[2,3] & Abarca J.[1,2]

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SUMMARY: The aim of the study was to determine the number and anatomical configuration of roots and root canals of maxillary first and second premolars using cone-beam computed tomography scans. n273 CBCT scans were evaluated, obtaining a sample of 592 maxillary premolars. Root number and root canal anatomy were categorized using Ahmed´s classification. Data was analyzed using Pearson's Chi-squared test. Two roots were present on 157 first premolars, one root in 132 premolars and three roots in 17. Second premolars presented one root in 266 samples and two roots in 20; no second premolars presented three roots. Eight different configurations were found; the most frequent was 2MP B1 P1 in first premolars (51,3 %) and 1MP1 (63.6 %) in second premolars. The most frequent morphology found in maxillary premolars in Chilean population was two and three roots. The analysis of internal anatomy using CBCT revealed a highly variable distribution of root canals, generally of low to medium complexity, similar to what is found in other ethnic groups.

KEY WORDS: Cone Beam Computed Tomography; Radicular Anatomy; Maxillary Premolar; Ahmed Classification; Root Canal Configuration.

INTRODUCTION

Endodontic treatment requires a broad knowledge of the external and internal anatomy of teeth, which allows proper access for the elimination of microorganisms and pulp tissue, andcorrect management of the apical zone (Ahmed *et al*., 2017). Maxillary premolars are one of the most commonly intervened maxillary teeth after first molars (Yousuf *et al*., 2015). Different studies have shown that the external and internal anatomy of these teeth is highly variable, considering that root number ranges from one to three and many different root canal configurations are possible (Pécora *et al*., 1993; Vertucci, 2005; Estrela *et al*., 2015; Bürklein *et al*., 2017; Saber *et al*., 2019). As anatomical complexity in premolars increases, so do procedural errors and associated apical periodontitis (Nascimento *et al*., 2019).

Ethnic and geographical origins (Vertucci; Abella *et al*., 2015; Ahmed *et al*.; Bürklein *et al*.; Martins *et al*., 2017) which makes it relevant to obtain specific data from Latin America differs significantly (Rocco *et al*., 2002).

Cone-beam computed tomography (CBCT) is a useful diagnostic tool for the evaluation and planning of endodontic treatment since it gives a detailed three-dimensional image of oral and maxillofacial structures (Patel *et al*., 2019). Its use in anatomical studies presents many advantages over other methods of analysis, such as non-invasiveness, high resolution, adjustable field of view, low radiation dosage when last generation equipment is used (Patel *et al*.) and the possibility of studying large samples to determine prevalence (Martins *et al*., 2019).

Radicular internal anatomy has been described using different classification systems, such as the one proposed by Vertucci in 1974, and Weine in 1982 (Vertucci), which are among the most frequently used. However, these classifications do not manage to describe the number and configuration of roots of maxillary premolars because of their high anatomical complexity (Ahmed *et al*.,). Moreover, more anatomical variations are reported when using a more

[1] Graduate Program, Faculty of Dentistry, Universidad San Sebastian, Santiago de Chile.
[2] Faculty of Dentistry, Patagonia Campus, Universidad San Sebastian, Puerto Montt, Chile.
[3] Center for Research in Epidemiology, Economics and Oral Public Health (CIEESPO), Faculty of Dentistry, Universidad de La Frontera, Temuco, Chile.

extensive range of imaging devices (Leoni *et al*., 2014; Saber *et al*.). In an attempt to find a logical and straightforward solution to these problems, a new system for the classification of root number and root canal configuration was proposed (Ahmed *et al*.,).

Even though root anatomy and canal configuration have been frequently studied in all tooth types, maxillary premolars have not been analyzed in a Chilean population.

This study aimed to determine the number of roots and root canals in first and second maxillary premolars; and categorize them using the anatomical classification proposed by Ahmed *et al*., through the use of CBCT images.

MATERIAL AND METHOD

A descriptive cross-sectional study was performed, previous authorization of the ethics committee of the Faculty of Dentistry of San Sebastian University (Resolution Number 2019-52). The research took place using archives of CBCT scans of Radiomax Radiological Center, San Fernando, Chile, taken between August 2017 and December 2018 as part of dental treatment planning. Personal data from patients were protected, as established by the Helsinki declaration. CBCT scans were acquired by qualified personnel using a Vera view epocs 3D R100 (J Morita MFG Corp, Kyoto, Japan) operating with 90kV and 6mA, and a voxel size of 125um (pulsed exposition, effective dose 6.34mSv). The inclusion criteria were comprised of maxillary CBCT scans with good quality images and the presence of maxillary premolars with complete radicular formation. Exclusion criteria were the presence of noise on images, premolars with immature apices, previous endodontic treatment, internal or external radicular resorption, apical surgery, restorations close to the pulp chamber, and the presence of artifacts preventing proper observation.

Before the analysis of the CBCT scans, the observers went through a two-stage calibration process. First was a theoretical part in which the expert and the observers defined observation parameters and secondly a practical step in which each observer randomly selected ten CBCT scans and analyzed root number and root canal number and disposition according to the criteria presented by Ahmed *et al*., on first and second maxillary premolars. Root and root canal anatomy, according to Ahmed, is classified in the following way: Each tooth is classified according to either tooth type (e.g. MP = Maxillary Premolar) or tooth number (e.g. 24 or 15), and a superscriptspecifies the number of roots on the left side: a two rooted maxillary premolar would be presented as 2MP.Root canal configuration is specified on the right using letters to identify root position (buccal root = B; mesiobuccal root = MB). Numbers are used to identify root canal morphology in three specific points: starting from the orifice, through the canal and to the foramen. For example, a maxillary premolars with two roots, a canal that divides in the middle third and joins in the apical third on the buccal root, and a single canal on the lingual root would be classified as: 2MP B2-1 L1. Another example would be a maxillary premolar with one root and a single canal at the orifice that divides into two canals all the way to the foramen: 1MP1-2.

The images obtained were analysed using the I Dixel software (J Morita MFG Corp, Kyoto, Japan) in a dark room on 15" LCD monitors with a resolution of 1920 ¥ 1080 pixels (LG®). Fifteen days later, the process was repeated under the same observational conditions. With these results, an intra and inter-observer concordance agreement was calculated with the Kappa coefficient, obtaining a force of 1,0 (perfect agreement) for both observations ($p>0.05$). Each observer analyzed ten CBCT scans per day. Each tooth was first adjusted to its major axis, and the number of roots was determined on the coronal window. To determine the number and disposition of root canals, the axial window was analyzed covering the root´s entire length and divided by root thirds (coronal near the cemento-enamel junction; middle halfway the total root length and apical 2mm from the root´s apex) (Fig. 1).

A descriptive analysis was conducted to establish the distribution of the study variables. Pearson's chi-squared test for qualitative variables was used for comparison between groups. For all cases a level of significance of 0.05 was considered. The results were presented throughfrequency distribution tables. The data were processed with the STATA 15 software (Stata Corp LP, USA).

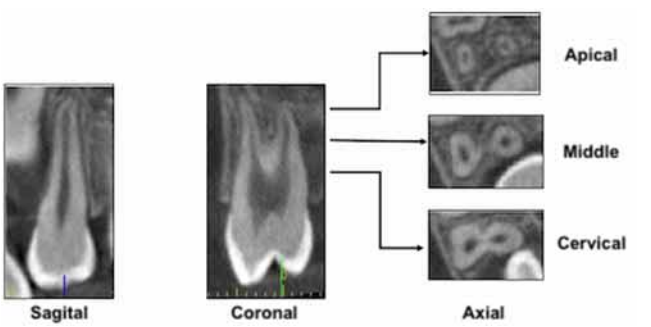

Fig. 1. CBCT images of a maxillary first premolar in the sagittal, coronal and axial plane, which was divided by root thirds: coronal, middle and apical.

RESULTS

A total of 273 CBCT scans and 592 maxillary premolars were analyzed; 306 corresponded to first premolars and 286 to second premolars. The sample was comprised of 332 women and 260 men, ranging from 13 to 73 years of age, with an average age of 54.

In terms of root number frequency, the differences were statistically significant (p=0.001): one root was found in 93 % of second premolars vs. 43 % of first premolars; two roots were present in 7 % of second vs. 51 % of first premolars, and three roots were present in 5.6 % of first and 0 % of second premolars (Table I). In the analysis of root canal number, differences were also statistically significant (p=0.001): one canal was observed in 63.6 % of second premolars and 11 % of first premolars; two canals were observed in 83.3 % of first and 36.4 % of second premolars and three canals were present on only first premolars (5.6 %) (Table II).

The most frequent configuration found on first premolars was2MP B1 P1 (51.3 %), which translates to two roots, each with an independent canal from the cemento-enamel junction to the apex. In the second premolars, the most frequent configuration was1MP1, one root and one canal (63.6 %). The configurations1MP2-1 (two canals that join and finish apically as one) and 1MP1-2-1(one canal divides in the middle third and joins again before reaching the apex), followed in frequency with 13.6 % and 9.8 % respectively (Table III and Fig. 2).

Table I. Root Number of maxillary premolars.

		Root Number			Total
		1	2	3	
Tooth Type	First Premolars	132 (43.1 %)	157 (51.3 %)	17 (5.6 %)	306 (100 %)
	Second Premolars	266 (93 %)	20 (7 %)	0 (0 %)	286 (100 %)
	Total	398 (67.2 %)	177 (29.9 %)	17 (2.9 %)	592 (100 %)

Table II. Root canal number of maxillary premolars.

		Root Canal Number			Total
		1	2	3	
Tooth Type	First Premolars	34 (11.1 %)	255 (83.3 %)	17 (5.6 %)	306 (100 %)
	Second Premolars	182 (63.6 %)	104 (36.4 %)	0 (0 %)	286 (100 %)
	Total	216 (36.5 %)	359 (60.6 %)	17 (2.9 %)	592 (100 %)

Table III. Root and root canal configuration, according to Ahmed´s Classification of first and second premolars.

		First premolars	Second premolars	Total
Root and root canal configuration	^{1} MP ^{1}	34 (11.1 %)	182 (63.6 %)	216 (36.5 %)
	^{1} MP $^{1-2-1}$	13 (4.2 %)	28 (9.8 %)	41 (6.9 %)
	^{1} MP $^{2-1}$	62 (18 %)	39 (13.6 %)	101 (15.8 %)
	^{1} MP ^{2}	16 (5.2 %)	6 (2.1 %)	22 (3.7 %)
	^{1} MP $^{1-2}$	19 (4.5 %)	15 (3.4 %)	34 (4.1 %)
	^{1} MP $^{2-1-2}$	0 (0 %)	1 (0.3 %)	1 (0.2 %)
	^{2} MP B^{1} P^{1}	157 (51.3 %)	20 (7 %)	177 (29.9 %)
	^{3} MP MB^{1} DB^{1} P^{1}	17 (5.6 %)	0 (0.0 %)	17 (2.9 %)
		306 (100 %)	286 (100 %)	592 (100 %)

DISCUSSION

A thorough understanding of the internal anatomy is of utmost importance to obtain success in endodontics. To our knowledge, this is the first in vivo study conducted in a Chilean subpopulation about the internal anatomy of maxillary premolars. In this population, the frequency of two roots in the maxillary first premolars was 51 % and 7 % for the second premolars. In addition, eight different root canal system configurations were found.

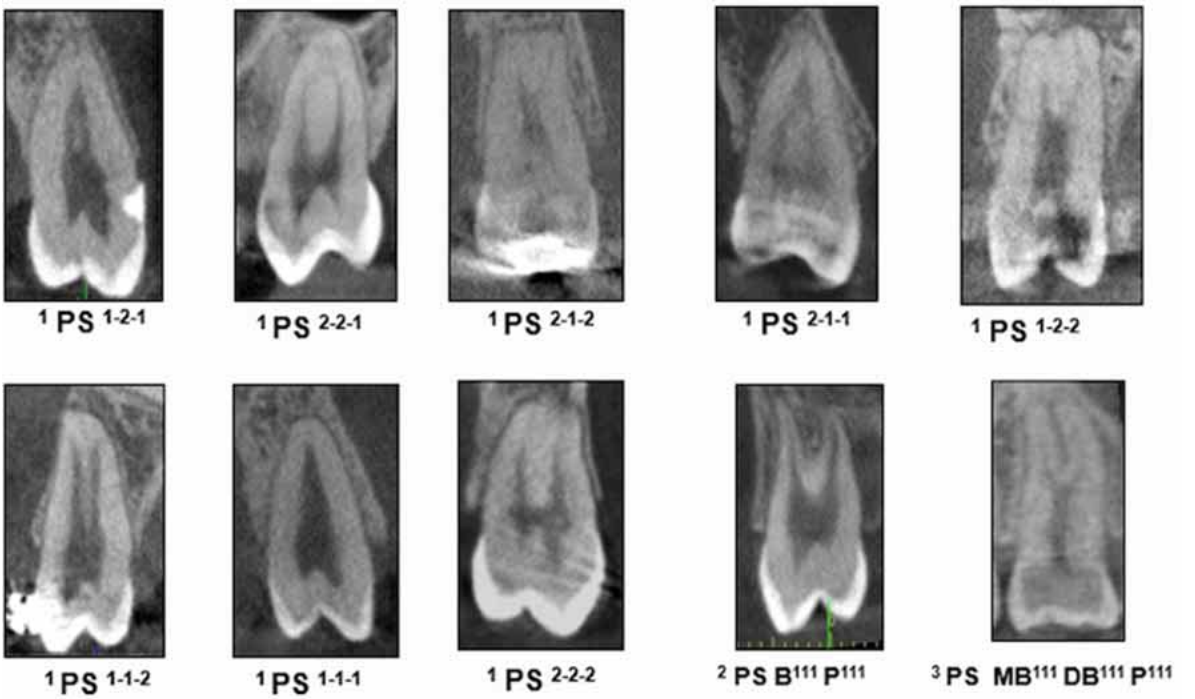

Fig. 2. CBCT images of the different configurations found in maxillary premolars, according to Ahmed´s classification.

Several studies have analyzed internal anatomy through CBCT imaging, and it has been observed that maxillary first premolars tend to present two roots, but according to geographical regions the frequency varies between 30.3 % on a Chinese subpopulation n (Li *et al*., 2018) to 80 % on a French (Monsarrat *et al*., 2016) and a Brazilian subpopulation (de Lima *et al*., 2019). There exist studies with similar results to those obtained in this research, like Abella *et al*., on a Spanish population and Vinothkumar *et al*., (2015) on an Indian population, who reported a frequency of two rooted first premolars of 51 % and Martins *et al*. (2017) in Portugal, who reported a frequency of 49 %. On the other hand, two-rooted second premolars are not very common, and its frequency varies from 5.6 % in Portugal (Martins *et al*., 2017) to 37.8 % in Georgia (Beshkenadze & Chipashvili, 2015). Regarding the presence of three roots in first premolars, the existing literature reports a low frequency between 0 % in China and Singapore and8.1 % in Kosovo and 9.1 % in Poland (Ahmad & Alenezi, 2016); in this study, a frequency of 5.6 % was observed. The absence of three roots in second premolars is in agreement with that observed in several subpopulations, including China (Guo *et al*., 2012), Portugal (Martins *et al*., 2017), and Brazil (Bueno *et al*.,).

Vertucci´s and Weine´s classification systems (Vertucci) are among the most frequently used methods to classify root canal anatomy; however, root canal anatomy varies greatly and using only four or eight different configurations can be challenging (Ahmed *et al*.,). Nevertheless, in this study, only eight configurations were observed. Ahmed´s anatomical classification (2016) adjusts to every single root and root canal anatomy, providing specific information about the tooth, favoring a proper coronal and radicular access. Its use has been proposed not only for investigational purposes but also for teaching and clinical practice (Ahmed & Dummer, 2018).In other tooth types, for example, mandibular molars, 32 different configurations were observed (Abarca *et al*., 2020); the reason why the number of configurations found was similar to what was observed by Vertucci (Vertucci) could be because maxillary premolars, especially second premolars, are the teeth that best adapt to this classification system (Vertucci). In a recently conducted study in a South-African subpopulation (Buchanan *et al*., 2020) 13 different configurations were observed for maxillary premolars, and in an Egyptian subpopulation, 11 different canal configurations were observed (Saber *et al*.). The configurations outside of the Vertucci classification corresponded to 1.1 % of the cases for both studies (Saber *et al*.; Buchanan *et al*.). Although new configurations were not found outside Vertucci´s classification, Ahmed´s classification system is more specific, provides more clarity about individual anatomy, and appears to be very helpful in describing complicated anatomy cases (Buchanan *et al*.,).

In first premolars, the most frequent root canal configuration (51.3 %) was 2MP B1 P1, two roots with one independent canal on each root, which is in agreement to what was observed by Saber *et al*. who found it to be 52.5 % and Buchanan *et al*., who reported that 97 % of two-rooted premolars presented this configuration (54.1 % had two roots). This configuration is similar to Vertucci´s type IV, which coincides with various published studies where this configuration is the most frequent (>50 %) in first premolars (Abella *et al*.,; Ahmad & Alenezi; Bürklein *et al*.,).

In one-rooted first premolars, multiple configurations were found, the most frequent configuration being1MP2-1(two canals from the cemento-enamel junction that join in the apical third) (17 %),which is similar to what was observed by Saber *et al*. with 15.6 %. This configuration is similar to Vertucci´s type II, with a prevalence in the existing literature of0 to 37.3 %, according to Ahmad & Alenezi. However, in a South African population, this type of configuration was only seen in 3.6 % of cases, and the most common configuration was 1MP2 (43.9 %) (Buchanan *et al*.,).

All three-rooted first premolars had an independent canal on each root (MB, DB, and P), which coincides with what was observed by Saber *et al*. in an Egyptian population. This configuration is similar to Vertucci´s type VIII configuration and matches with the anatomy observed in a study in a Spanish population (Abella *et al*.,) and a Chinese subpopulation (Tian *et al*., 2012). Buchanan *et al*., observed that the most common configuration of three-rooted premolars was type VIII, but also found one case with two canals on the Distobuccal root in the middle third. In a study by Beltes *et al*., (2017), who analyzed three rooted premolars specifically, they found less common configurations that include partial fusion of buccal roots or fusion of the Distobuccal to the palatal root and even the presence of C-shaped canals in fused buccal roots.

In one-rooted second maxillary premolars (93 %), diverse configurations were observed, the most frequent one being1MP1 (64 %); t his is in agreement with what was observed by Abella *et al*., Felsypremila *et al*. (2015), Martins *et al*. (2018) and Buchanan *et al*. The configurations that followed in frequency were 1MP1-2-1 with 10 % and 1MP2-1 with 8 %. The most common canal configurations found by Saber in an Egyptian population were 1MP2-1 (22.2 %), 1MP2 (18.4 %), and 1MP1 (16.1 %) (Saber *et al*.), which is different from what was observed in our subpopulation. A study conducted on a German subpopulation also shows different results in second maxillary premolars, where the most frequent types were IV (2-2), V (1-2), and VI (2-1-2) (Bürklein *et al*.,).

Few studies have been conducted using the new classification system, so it is difficult to compare the results obtained in this study. However, from what has been gathered comparing them to an Egyptian population, a South African subpopulation and to other populations that used Vertucci´s classification (Ahmad & Alenezi; Saber *et al*.; Buchanan *et al*.). It appears that Vertucci´s type IV configuration or Ahmed´s 1 or 2MP2is the more prevalent configuration for first premolars in different ethnic groups. However, in terms of root number, there appears to be an ethnic involvement. Two-rooted and three-rooted first premolars appear to be a European trait (Beltes *et al*.,) that may have developed in the Modern Period, through a diversification in haplo groups that occurred in that time (Przesmycka *et al*., 2020); and one-rooted first premolars could be considered an Asian trait (Martins *et al*., 2018, 2019). The Chilean population is a mixture of European and Native American ethnicity (Rocco *et al.*), which might explain the more than average percentage of two and three roots found in this study.

CONCLUSION

The analysis of the internal anatomy of maxillary premolars through CBCT images using Ahmed´s classification revealed eight different root canal system configurations. The most frequent morphology found on a Chilean Population was two roots and two canals in first premolars (2MP B1 P1) and one root and one canal in second premolars (1MP1). The study of internal anatomy is of high importance to obtain an optimal treatment and clinical success. Chilean anatomy of maxillary premolars can be generally considered to be of low to medium complexity, similar to what is found in other ethnic groups.

MONARDES, H.; HERRERA, K.; VARGAS, J.; STEINFORT, K.; ZAROR, C. & ABARCA, J. Anatomía de la raíz y configuración del conducto de los premolares maxilares: estudio de tomografía computarizada de haz cónico. *Int. J. Morphol., 39(2)*:463-468, 2021.

RESUMEN: El objetivo de este estudio fue determinar el número y la configuración de raíces y canales radiculares de primeros y segundos premolares maxilares utilizado tomografía computacional de haz cónico. 273 TCHC fueron evaluados, obtenido una muestra de 592 premolares maxilares. El número de raíces y la anatomía de los canales radiculares fueron categorizados utilizando la clasificación de Ahmed. Los datos fueron analizados con la prueba Chi- Cuadrado de Pearson. Dos raíces fueron observadas en 157 primeros presentaron una raíz en 266 muestras y dos raíces en 20; no se encontraron tres raíces en segundos premolares. Ocho diferentes configuraciones fueron encontradas; siendo la más frecuente 2MP B1 P1 en primeros premolares (51,3 %) y 1MP1

(63,6 %) en segundos premolares. La morfología radicular más frecuentemente encontrada en premolares de población Chilena fue de dos y tres raíces. El análisis de la anatomía interna usando TCHC mostró una gran variabilidad de en la distribución de los canales radiculares. Generalmente de mediana y baja complejidad como los encontrados en otros grupos etnicos.

PALABRAS CLAVE: Tomografía computacional de haz cónico; Anatomía Radicular; Premolares Maxilares; Clasificación Ahmed; Configuración Canal radicular.

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Corresponding autor:
Jaime Abarca
Facultad de Odontología
Universidad San Sebastián
Lago Panguipulli 1390
Pelluco Alto - Puerto Montt
CHILE

Email: jaime.abarca@uss.cl

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