

# Root and Root Canal System Morphology of Maxillary First Premolars in a Chilean Subpopulation: A Cone-Beam Computed Tomography Study

Morfología Radicular y del Sistema de Canales Radiculares de los Primeros Premolares Maxilares en una Subpoblación Chilena: Un Estudio de Tomografía Computarizada de Haz de Cono

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**SUMMARY:** The maxillary first premolar (MFP) presents a highly variable and complex root morphology; it is also one of the teeth most likely to suffer vertical root fractures. The aim of this study was to describe the morphology of the root and root canal system of the MFP in a Chilean population using Cone-Beam Computed Tomography (CBCT). One hundred and twenty-one MFP were evaluated (60 left and 61 right), belonging to subjects of both sexes. Descriptive and statistical analysis of the data was carried out, with a value of  $P < 0.05$  being statistically significant. One root was observed in 71 % of teeth and two roots in 29 %; statistically significant differences were observed in the number of roots by sex ( $p < 0.05$ ). Two root canals were found in 69.5 % of teeth and one canal in 30.5 %. In terms of morphological classification, 41.3 % of cases were Vertucci Type IV. The proximal cementodentinal walls were the thinnest. The MFP presented a high degree of morphological variation in a Chilean subpopulation.

**KEY WORDS:** Maxillary first premolar; Root morphology; Cone beam tomography; Endodontics.

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## INTRODUCTION

The morphology of the root canal system (RCS) is unpredictable and unique for every tooth of the stomatognathic apparatus. Various studies have determined that the maxillary first premolar (MFP) presents a highly variable and complex root morphology, especially in the apical region (Abella *et al.*, 2015; Li *et al.*, 2018; Kfir *et al.*, 2020). Differences in the configuration of the pulp chamber, narrow entrances at the fork, and deep mesial concavities make the MFP a difficult tooth to treat endodontically, and thus a permanent challenge to the clinician (Kfir *et al.*). Although the morphology of the MFP has usually been described as having one root (36 %) (Kfir *et al.*) or two roots (80.2 %) (de Lima *et al.*, 2019), a third root has been reported in 2.6 % of cases (Abella *et al.*). Variations in the number of roots, root canals, and morphological classification are attributed to factors like age, sex and ethnic group (Abella *et al.*).

It has been stated that the MFP is among the teeth most likely to suffer vertical root fracture (VRF) (Awawdeh *et al.*, 2008; PradeepKumar *et al.*, 2016). VRF is a serious clinical problem, since once it has occurred the only treatments available are extraction of the tooth or resection of the root. The occurrence of VRF is associated principally with incorrect distribution of forces along the longitudinal axis of the root, which is directly related with dentine thickness (Chai & Tamse, 2015), the external morphology of the root (Sathorn *et al.*, 2005) and the mesiodistal diameter (Chai & Tamse). VRF has also been related with excessive elimination of dentine and the appearance of microcracks in the root structure, generated by new trends in mechanised preparation (PradeepKumar *et al.*).

Cone beam computed microtomography (CBCT) is

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a widely accepted, non-invasive tool for morphological study of the teeth and adjacent structures, due to its great precision and detailed results (Betancourt *et al.*, 2016). With CBCT it is possible to explore the maxillofacial skeleton in a three-dimensional reconstruction, in which 1:1 scale measurements can be taken of the root length and the thickness of the cementodentinal walls (Kfir *et al.*).

To the best of our knowledge, information on morphological studies of the MFP in the Chilean population is limited. The aim of this study was therefore to describe the morphology of the root and RCS of the MFP in a Chilean population using CBCT.

## MATERIAL AND METHOD

The study was approved by the Scientific Ethics Committee (CEC) of Universidad de La Frontera, Temuco, Chile (Protocol 082/20). All the patient personal information was anonymized, except their age and sex. The methodological design of the study was cross-sectional, descriptive and observational *in vivo*. The root morphology of MFP was examined using images from 68 CBCT examinations of patients of both sexes (39 women, 29 men), provided by the radiology unit of the Dental Faculty of Universidad de La Frontera, Temuco, Chile. Both premolars, left and right, were included. The CBCT images used had been requested as part of examination, diagnosis and dental treatment planning, between the months of November 2018 and May 2021. The examinations were taken with a Pax Zenith CBCT unit, Vatech (Korea, 2011), with the following parameters: 90 kV and 120 mA; FOV 8 x 6 cm, voxel size 0.12 mm. The images were processed with the Ez 3D 2009 software and projected on a 49" LG LED screen, Model 49UK6200PSA.

The images were analysed by 2 investigators, with prior intra and inter-observer calibration. The intra and inter-class coefficient of correlation presented a force of 1.0 (perfect concordance) for both observations ( $p > 0.05$ ). When no consensus could be reached, the decision was taken by a radiology specialist with experience in endodontics. Each investigator assessed the CBCT images twice, with an interval of two weeks between assessments.

A total of 121 MFP were analysed (60 left and 61 right), belonging to subjects of both sexes, aged between 13 and 62 years. In every image complete root formation was observed and the quality of the image was sufficiently clear. MFP were excluded in which any of the following were identified: obturation with gutta-percha, rehabilitation with

fixed prosthesis, calcification of the root canals or evidence of root surgery.

The analysis was standardised using the following methodology (Betancourt *et al.*): the MFP was located and a corono-apical exploration was made of the whole length of the root. To do this the axial plane was rectified, orienting the sagittal and coronal planes to bring them parallel with the longest axis of the root. Then the total length of the tooth was measured from the apex of the root to the tip of the highest cusp, using the coronal plane window. Sections of the image were obtained in the axial plane at intervals of 0.5 mm and a thickness of 1 mm for all the samples using multiplanar reformatting (MPR). Apico-coronal exploration followed the axial axis of each tooth to determine the number of roots and number of root canals, and to classify the morphology of the canal system as per Vertucci (1984) (Fig. 1). To determine the thickness of the cementodentinal wall, the vertex of each root was located and apico-coronal exploration was carried out in 2 mm sections, observing the surfaces at 2, 4 and 6 mm. To determine the thickness of the cementodentinal wall, a straight line was drawn from A (most concave point of the canal wall) to B (external surface of the root wall analysed). This procedure was repeated for each wall (vestibular, palatine, mesial and distal) of each root surface analysed (Matus *et al.*, 2017). The data collected were recorded in a Microsoft Office Excel spreadsheet (Microsoft Office, USA). Descriptive analysis of the data was carried out to determine the means (M) and standard deviations (SD). Statistical analysis consisted of applying the Kolmogorov-Smirnov normality test, the t-test for independent samples, the t-test for related samples, the Mann-Whitney U test for independent samples, the Wilcoxon test for related samples and the Chi-squared test. The data were analysed using the IBM SPSS Statistics Programme (version 23.0). A value of  $p < 0.05$  was selected as the threshold of statistical significance.

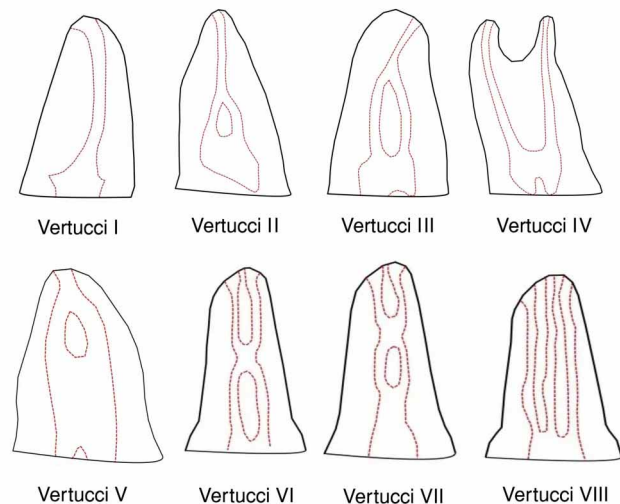


Fig. 1. Vertucci's morphological classification of root canal systems.

## RESULTS

A total of 121 MFP were analysed, of which 71 % presented one root (84.3 % in women and 53 % in men) and 29 % presented two roots (15.7 % in women and 47 % in men); statistically significant differences were observed in the number of roots by sex ( $p < 0.05$ ) (Table I). Sixty-nine point five percent of the teeth presented two root canals (78.4 % in men and 62.9 % in women), while 30.5 % of the cases showed one root canal (37.1 % in women and 21.6 % in men); no statistically significant differences were observed

in the number of root canals by sex ( $p > 0.05$ ) (Table II). Regarding the morphological classification, 41.3 % of the cases were Vertucci Type IV, 31.4 % were Type I, 16.5 % Type II, 10 % Type III and 0.8 % Type V ( $p < 0.05$ ) (Table III). Figure 2 shows a visual representation of the morphological types found. The mean length was 19 mm for the right MFP and 18.8 mm for the left. The buccal and palatal walls were the thickest, while the proximal walls were the thinnest (Table IV). At the 2 mm level, statistically significant differences were apparent between men and women ( $p < 0.05$ ). The mean age of the study participants was 31.5 years.

Table I. Prevalence of the number of roots of the MFP by sex and position in the maxilla.

Number of Roots	Sex			Tooth Position		
	Male	Female	Total	Right Mfp	Left Mfp	Total
One Root	27 (53,0 %)	59 (84,3 %)	86 (71,1 %)	43 (70,5 %)	43 (71,7 %)	86 (71,0 %)
Two Roots	24 (47,0 %)	11 (15,7 %)	35 (28,9 %)	18 (29,5 %)	17 (28,3 %)	35 (29,0 %)
Total	51 (100 %)	70 (100 %)	121 (100 %)	61 (100 %)	60 (100 %)	121 (100 %)

Table II. Prevalence of the number of root canals of the MFP by sex and position in the maxilla.

Number of Root Canals	Sex			Tooth Position		
	Male	Female	Total	Right Mfp	Left Mfp	Total
One Canal	11 (21,6 %)	26 (37,1 %)	37 (30,6 %)	20 (32,8 %)	17 (28,3 %)	37 (30,5 %)
Two Canals	40 (78,4 %)	44 (62,9 %)	84 (69,4 %)	41 (67,2 %)	43 (71,7 %)	84 (69,5 %)
Total	51 (100 %)	70 (100 %)	121 (100 %)	61 (100 %)	60 (100 %)	121 (100 %)

Table III. Distribution of the MFP following Vertucci's morphological classification, by sex and position in the maxilla.

Tooth Position /Sex	Vertucci's Root Canal Configuration					Total
	Type I	Type II	Type III	Type IV	Type V	
Right Maxillary First Premolar/ Male	6 (23.1 %)	5 (19.2 %)	2 (7.7 %)	13 (50.0 %)	0 (0.0 %)	26 (100 %)
Right Maxillary First Premolar / Female	14 (40.0 %)	4 (11.4 %)	4 (11.4 %)	12 (34.3 %)	1 (2.9 %)	35 (100 %)
Left Maxillary First Premolar / Male	6 (24.0 %)	5 (20.0 %)	2 (8.0 %)	12 (48.0 %)	0 (0.0 %)	25 (100 %)
Left Maxillary First Premolar/ Female	12 (34.3 %)	6 (17.1 %)	4 (11.4 %)	13 (37.1 %)	0 (0.0 %)	35 (100 %)
TOTAL	38 (31.4 %)	20 (16.5 %)	12 (9.9 %)	50 (41.3 %)	1 (0.8 %)	121 (100 %)

Table IV. Mean and standard deviation of measurements of the thickness of cementodentinal wall of the MFP in the apical third. BC: buccal canal; PC: palatine canal.

Root Canal	Section level from apex		
	2 mm	4 mm	6 mm
BC buccal	1.53 ±0.36	1.83 ±0.37	2.20 ±0.34
BC mesial	1.10 ±0.20	1.39 ±0.33	1.62 ±0.38
BC distal	1.06 ±0.31	1.38 ±0.33	1.68 ±0.34
BC palatine	1.61 ±0.41	1.79 ±0.49	2.30 ±0.36
PC buccal	1.25 ±0.30	1.48 ±0.39	1.89 ±0.29
PC mesial	1.11 ±0.25	1.33 ±0.28	2.01 ±0.30
PC distal	1.13 ±0.34	1.36 ±0.25	1.70 ±0.29
PC palatine	1.37 ±0.41	1.70 ±0.28	2.08 ±0.31

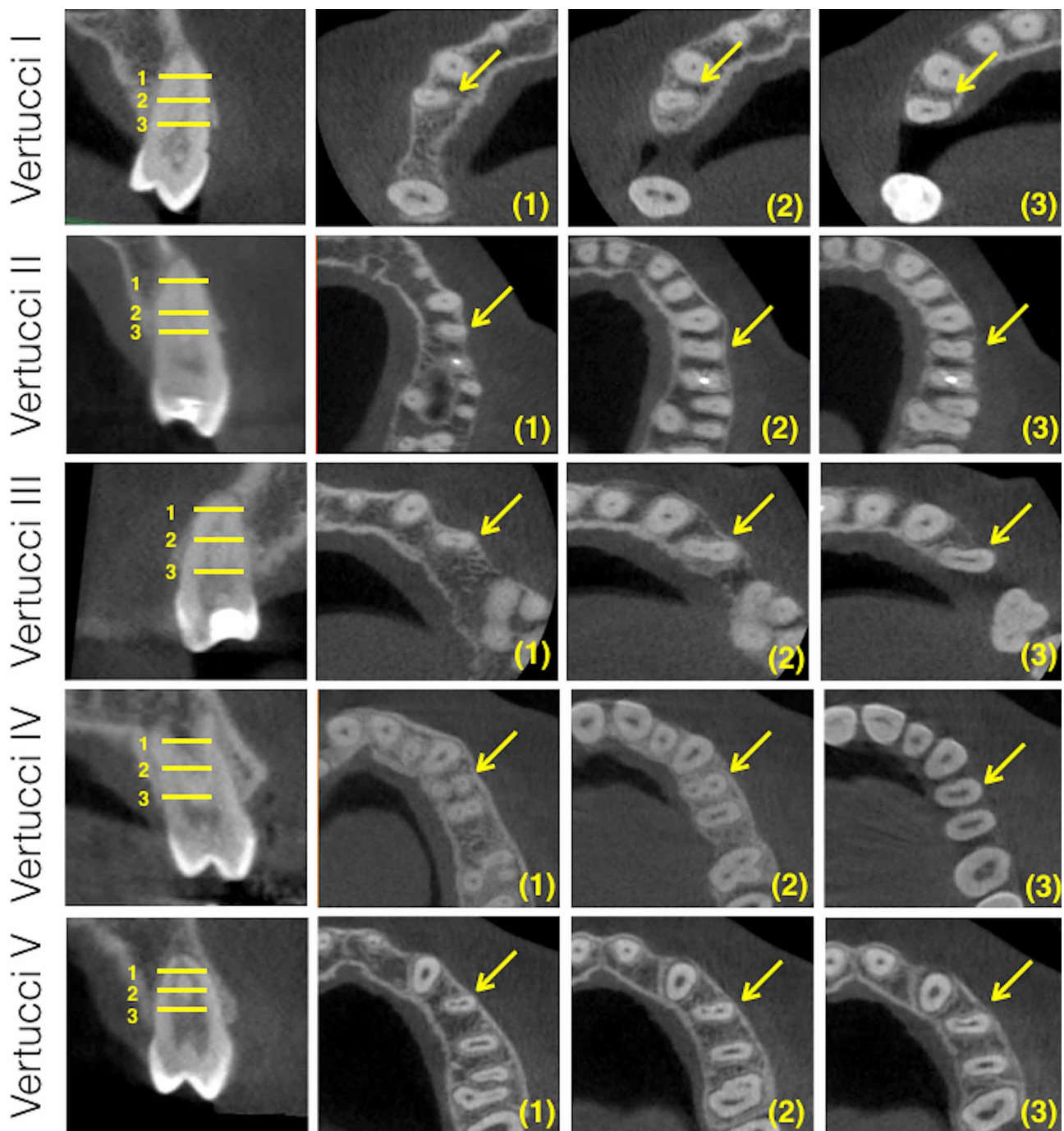


Fig. 2. CBCT image of the morphology of the root canal system of the maxillary first premolar, following Vertucci's classification. Axial section of the tooth at 1) apical, 2) middle and 3) coronal levels. The bars indicate the root segment analysed and the yellow arrows indicate the tooth examined.

## DISCUSSION

Of the whole sample analysed, 71 % presented one root and 29 % two roots. This is consistent with the high

prevalence of one root reported in Chinese (Walker, 1987) and Brazilian populations (Pécora *et al.*, 1992). Similar

results were reported in a CBCT study in a Chinese population, with one root observed in 66 % and two roots in only 33 % of cases (Tian *et al.*, 2012). On the other hand, these results contrast with reports of studies in European, Brazilian and African populations, in which over 50 % of MFP presented two roots while no more than 3 % had a third root (de Lima *et al.*; Abella *et al.*; Buchanan *et al.*, 2020; Kfir *et al.*). A recent literature review confirmed greater frequency of two roots (57 %) than one (41 %) (Ahmad & Alenezi, 2016). The differences described may be due to the different methodological designs used and the racial influence of each population. Furthermore, the lack of a standardised CBCT protocol may also influence the results reported.

In the present work, 69.5 % of the cases presented two root canals, followed by 30.5 % with one. These observations agree with previous studies which reported similar ranges to our results (Awawdeh *et al.*; Tian *et al.*; Abella *et al.*). Li *et al.* and Kfir *et al.* have recently reported prevalence of two canals of 87.5 % in a Chinese population and 95 % in an Israeli population respectively, higher than the percentage reported in the present article.

There is limited scientific evidence for morphological study of MFP in Chile. Matus *et al.* (2020) were the first to describe the morphological characteristics of the MFP in a Chilean population by CBCT. The frequency and the distribution by side and sex of the number of roots and root canals reported are similar to those observed in the present article. The results are therefore consistent, since the study was carried out in the same region of the country. It should be noted however that the number of samples in our study was higher (n=121), and that our study included the configuration of the RCS, not analysed previously. Monardes *et al.* (2021) carried out CBCT analysis of 592 maxillary premolars in a Chilean population, which included 306 MFP. The age range studied was from 13 to 73 years, a similar range to that of the present study. They observed 43.1 % of MFP with one root, 51.3 % with two roots and 5.6 % with three roots. These observations disagree with our results, which reported one root in most cases (71.0 %), followed by two roots (29.0 %). The differences between these two studies may be because the sub-populations studied belong to two different regions of the country. Their results for the number of root canals were 83.3 % with two canals, followed by one canal, similar to the results shown here. An important point is that Monardes *et al.* did not evaluate the distribution of the canals and the number of roots by side or by sex in their study, so full discussion of the results is impossible.

The most frequent Vertucci configuration in our study was Type IV (41.3 %), followed by Type I (31.4 %). These

observations are consistent with CBCT studies in populations in Spain, Brazil, China, South Africa, Saudi Arabia and Israel, which all reported that Vertucci Type IV was the most frequent configuration (over 50 %) (Abella *et al.*; of Lima *et al.*; Buchanan *et al.*; Kfir *et al.*; Al-Zubaidi *et al.*, 2021). Our results also agree with Monardes *et al.*, who found that the most prevalent morphological configuration in a Chilean population was 2MP B1 P1 using Ahmed's classification (Ahmed *et al.*, 2017), equivalent to Vertucci Type IV. However these observations differ from those reported in a Pakistani population, where Vertucci Type I was the most prevalent (68.6 %), followed by Type II (31.5 %) (Nazeer *et al.*, 2018).

Analysis of our sample showed that the proximal walls were thinner than the buccal and palatine. These observations are consistent with the findings in a Chilean population of Matus *et al.* (2020), who stress the importance of correct treatment planning to avoid perforations or unnecessary structural weakening of the tooth.

## CONCLUSIONS

The morphology of the MFP presented great variation. Most MFP in a Chilean subpopulation had 1-root with 2 root canals. The most common canal configuration found was Vertucci type IV. Considering the limited thickness of the proximal cementodentinal walls, conservative preparation techniques must be considered. The use of CBCT can provide an image of greater diagnostic value in complex morphological cases.

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**RESUMEN:** El primer premolar maxilar (PPM) presenta una morfología radicular muy variable y compleja; también es uno de los dientes con mayor probabilidad de sufrir fracturas radiculares verticales. El objetivo de este estudio fue describir la morfología de la raíz y el sistema de conductos radiculares del PPM en una

población chilena mediante tomografía computarizada de haz cónico (CBCT). Se evaluaron 121 PPM (60 izquierdas y 61 derechas), pertenecientes a sujetos de ambos sexos. Se realizó un análisis descriptivo y estadístico de los datos, siendo estadísticamente significativo un valor de  $P < 0,05$ . Se observó una raíz en el 71 % de los dientes y dos raíces en el 29 %; se observaron diferencias estadísticamente significativas en el número de raíces por sexo ( $p < 0,05$ ). Se encontraron dos conductos radiculares en el 69,5 % de los dientes y un conducto en el 30,5 %. En cuanto a la clasificación morfológica, el 41,3 % de los casos fueron Vertucci Tipo IV. Las paredes cementodentinales proximales fueron las más delgadas. El PPM presentó un alto grado de variación morfológica en una subpoblación chilena.

**PALABRAS CLAVE: Primer premolar maxilar; Morfología de la raíz; Tomografía de haz cónico; Endodoncia.**

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