

EVALUATION OF THE ROOT MORPHOLOGY OF MANDIBULAR FIRST PREMOLARS USING CONE-BEAM COMPUTED TOMOGRAPHY IN A PERUVIAN POPULATION

Evaluación de la morfología radicular de primeros premolares mandibulares mediante tomografía computarizada de haz cónico en una población peruana

Olger Benavides-Guzman,¹ Yalil Rodríguez-Cárdenas,¹ Aron Aliaga-del Castillo,² Gustavo Armando Ruíz-Mora,³ Luis Ernesto Arriola-Guillén.⁴

1. Division of Oral and Maxillofacial Radiology, School of Dentistry, Universidad Científica del Sur, Lima, Perú.

2. Director, Graduate Orthodontic Clinic, University of Michigan, School of Dentistry, Department of Orthodontics and Pediatric Dentistry, USA.

3. Division of Orthodontics, Faculty of Dentistry, Universidad Nacional de Colombia, Bogota D.C, Colombia.

4. Division of Orthodontics and Division of Oral and Maxillofacial Radiology, School of Dentistry, Universidad Científica del Sur, Lima, Perú.

ABSTRACT

Introduction: The morphology of the root canal of the first premolars is not always the same and therefore a good knowledge of its dental anatomy is essential. **Aim:** To assess the morphology of roots and root canals of mandibular first premolars in a Peruvian population using cone-beam computed tomography (CBCT).

Materials and Methods: This was a descriptive cross-sectional study. A total of 370 mandibular first premolars fulfilling the inclusion criteria were evaluated using CBCT, and the number of roots and root canals, the Vertucci's classification of root canal configuration, age, sex and side of the tooth were registered.

Results: One and two roots were presented in 96.2% (n=356) and 3.8% (n=14), respectively, of the mandibular first premolars analyzed, and one canal was present in 67.6% (n=250) and two canals in 32.2% (n=119). A type I root canal configuration was found in 67.6% (n=250) of the cases followed by type V with 26.2% (n=97). A statistically significant association was found between the number of roots and canals ($p<0.001$) and age also had a significant influence on this variable ($p=0.0043$).

Conclusions: The presence of one canal in mandibular first premolars is the most frequent, although there is a considerable prevalence of two in the population studied. The number of roots is associated with the number of canals, with age having a significant influence on these variables.

Keywords: Cone-Beam Computed Tomography; Mandibular first premolar; Vertucci Configuration; Anatomy, Radiology .

RESUMEN

Introducción: La morfología del canal radicular de los primeros premolares no siempre es la misma y por ello es fundamental un buen conocimiento de su anatomía dental. **Objetivo:** Evaluar la morfología de las raíces y conductos radiculares de primeros premolares mandibulares en una población peruana mediante tomografía computarizada de haz cónico.

Materiales y Métodos: Este fue un estudio transversal descriptivo. Se evaluaron mediante tomografías un total de 370 primeros premolares mandibulares que cumplían con los criterios de inclusión, y se registró el número de raíces y conductos radiculares, la clasificación de Vertucci de la configuración radicular, la edad, el sexo y el lado del diente. Se realizaron las pruebas de chi-cuadrado y una regresión logística binaria ($p<0,05$).

Resultado: Se presentó una y dos raíces en el 96,2% (n=356) y 3,8% (n=14), respectivamente, de los primeros premolares mandibulares analizados, y un canal estuvo presente en el 67,6% (n=250) y dos canales en el 32,2% (n=119). Se encontró una configuración del conducto radicular tipo I en el 67,6% (n=250) de los casos seguido del tipo V con un 26,2% (n=97). Se encontró una asociación estadísticamente significativa entre el número de raíces y conductos ($p<0.001$) y la edad también influyó significativamente en esta variable ($p=0.0043$).

Conclusión: La presencia de 1 canal en primeros premolares mandibulares es la más frecuente, aunque existe una prevalencia considerable de 2 en la población estudiada. El número de raíces está asociado al número de canales, teniendo la edad una influencia significativa en estas variables.

Palabras Clave: Tomografía Computarizada Cone-Beam; Primer premolar mandibular; Configuración de Vertucci; Anatomía, Radiología.

CORRESPONDING AUTHOR: Luis Ernesto Arriola Guillén.
Division of Orthodontics, School of Dentistry, Universidad Científica del Sur, Lima, Perú. Phone: 992124507 E-mail: luchoarriola@gmail.com

CITE AS: Benavides-Guzman O, Rodríguez-Cárdenas Y, Aliaga-del Castillo A, Ruíz-Mora GA, & Arriola-Guillén LE. Evaluation of the root morphology of mandibular first premolars using cone-beam computed tomography in a peruvian population. J Oral Res. 2024;13(1):37-46. doi:10.17126/joralres.2024.004

Received: June 02, 2023.

Accepted: January 02, 2024.

Published online: April 08, 2024.

ISSN Print 0719-2460

ISSN Online 0719-2479.

INTRODUCTION

Endodontic treatment aims to treat periapical disease after complete disinfection and shaping of the root to create a three-dimensional seal.¹⁻³ However, the morphology of the canal of each tooth is not always the same in every individual, and therefore good knowledge of dental anatomy and the different types of current imaging exams is essential in order to achieve an accurate diagnosis and for treatment planning.^{3,4}

The root canal system has a complex anatomy, varying not only between different teeth but also between different people.⁵⁻⁹ According to the literature, mandibular first premolars are considered complex teeth to treat endodontically as they are usually expected to have a single root and a single canal.

However, a simple periapical radiograph prior to root canal treatment does not allow determination of the presence of a double canal or other morphological changes due to the overlapping of images. This is the main disadvantage of 2D radiographs and may produce complications before, during and after treatment. Thus, other imaging methods are needed to allow examination of the entire anatomy of the tooth and improve treatment planning.¹⁰⁻¹⁴

A review of the literature showed that in seven studies the majority of mandibular first premolars had 1 root and most had 1 root canal. The Vertucci type I classification was the most common canal configuration followed by type V.¹⁵⁻²¹ Root systems and root canals of mandibular first premolars have been evaluated in several studies in different populations and by different methods of identification.^{3,19,22}

Most of the samples of extracted teeth were examined with microtomography, which allows

the morphology of canals to be observed at a much smaller scale and with a much higher resolution but with the great disadvantage that the tooth must be extracted and this method is only available in a limited number of centers.²³

Recently, cone beam computed tomography (CBCT) has been increasingly consolidated as one of the best *in vivo* imaging tools to examine root and root canal systems of teeth. It is one of the most accurate imaging tests in the dental field and has several advantages that benefit the clinician and patients compared to other studies.²⁴⁻³⁰

The rationale of this study emphasizes its clinical implication since endodontists from this region will understand in greater detail the anatomy of the root canal of first premolars to obtain successful endodontic procedures. Furthermore, the literature review specifically does not mention the advantage of CBCT over 2D modalities for characterizing the root and root canal morphology of mandibular first molars. Therefore, the aim of this study was to evaluate the root and root canal morphology of mandibular first premolars in a Peruvian population using CBCT.

MATERIALS AND METHODS

This was a descriptive, retrospective, cross-sectional study in which the sample was composed of images of patients attended in a radiological center in Lima, Peru between the years 2018 and 2020. The present study was approved by the Ethics Committee of the *Universidad Científica del Sur*. The sample size was calculated by means of a pilot test, with a proportion with a confidence level at 95%, a precision at 5% and a proportion at 40% were estimated according to the study of Bürklein *et al.*,¹⁰ suggesting a sample size of 370 mandibular first premolars.

CBCT scans with a field of view of 12 cm x 9 cm were performed in teeth 34 and 44 fulfilling the inclusion criteria.

Teeth with active orthodontic treatment, with evident pathologies in the tooth root or with calcification were excluded. Scans presenting any type of artifact, movement, premolars with root canal treatment, pathology, calcification, trauma or root resorption were discarded. The tomographic study was carried out with Point 3D Combi 500® equipment [Pointnix, Kuro-Dong, Kuro-ku, Seoul, Korea].

The parameters of the equipment were 5 mA, 80 kvp, voxel size 0.256 mm, exposure time 19 seconds and 180 degrees of rotation. All helical computed tomography images were performed with low-dose radiation by a trained medical imaging technologist and were reviewed by a specialist in oral and maxillofacial radiology to obtain good quality images. The volumes were evaluated in Real Scan software [Version 2.0, Pointnix, Kuro-

Dong, Kuro-ku, Seoul, Korea] on a monitor [LG 20MK400H, China].

In the evaluation, the three spatial planes were manipulated, starting with the axial plane, since it is very useful to determine how many roots the tooth has. The mandibular first premolars were evaluated from the cervical root third to the apical root third with a slice thickness of 1 mm and a minimum distance of 0.5 mm between each slice. Then, in the coronal plane the axial axis of the premolar was fixed by also manipulating the sagittal plane, corroborated with a transaxial slice at the level of the mandibular first premolar using the same parameters as the axial slice in order not to miss any detail.

Evaluation of all the mandibular first premolars included the number of roots, number of canals and the type of canal according to the Vertucci's classification of root canal configuration (Figure 1, Figure 2 and Figure 3).^{11,31}

Figure 1. Scheme of Vertucci's classification of root canal configuration.

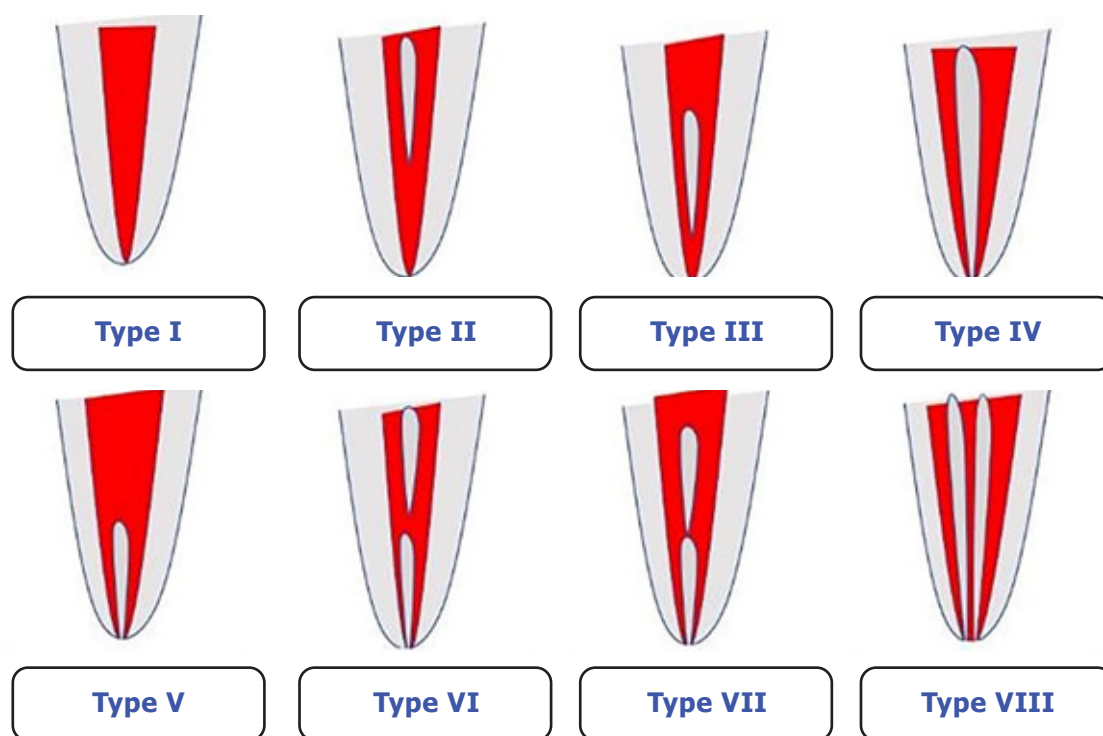


Figure 2. Axial section of mandibular first premolars showing the root configuration, finding in some cases a single root (image on the left side, single arrow pointing to it) and in other cases 2 roots (image on the right side, with both arrows pointing to the condition).

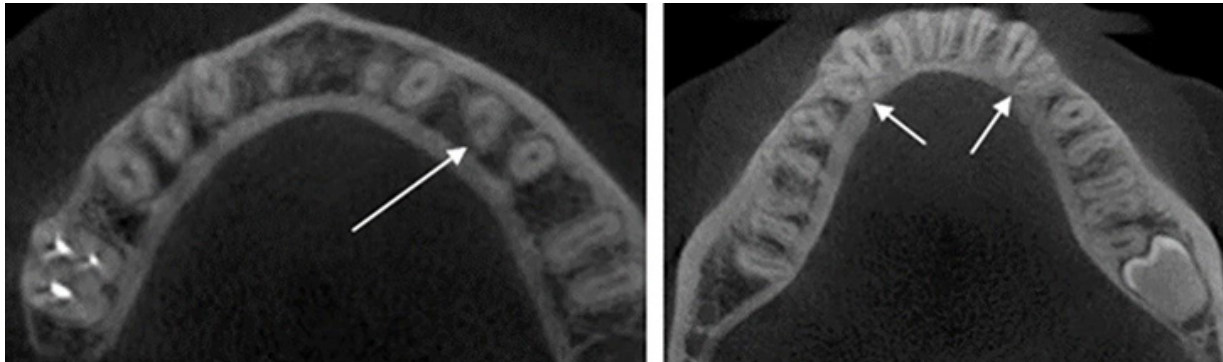
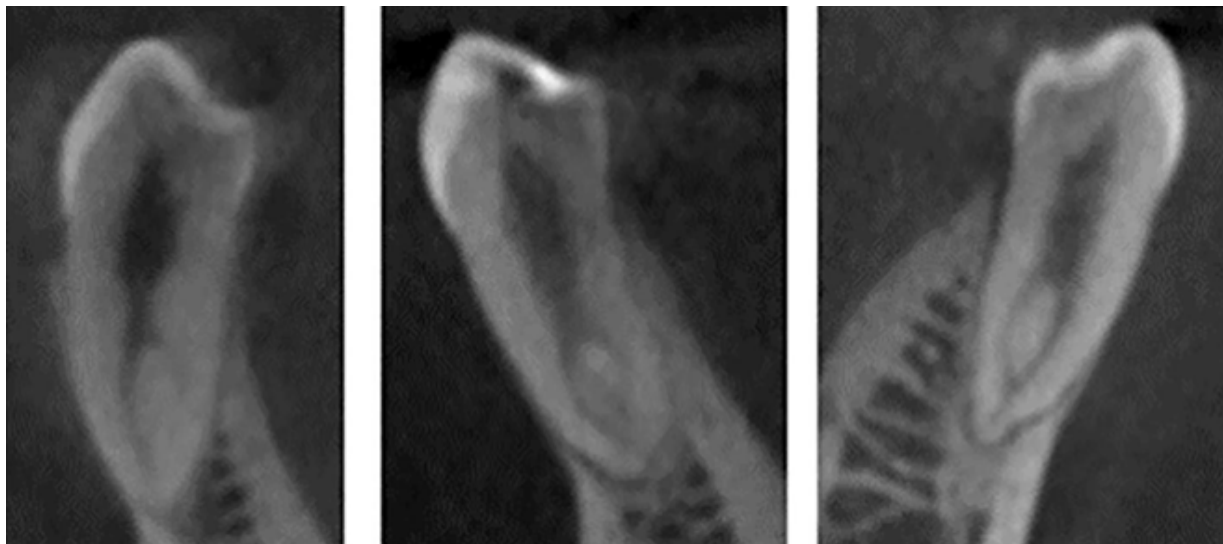


Figure 3. Representative images of how trans axial cuts help determine type III of the Vertucci's classification of root canal configuration.



The evaluation of the mandibular first premolars was performed by the researcher and an experienced radiologist to obtain accurate measurement of the variables in order to achieve adequate concordance with reliable results.

Statistical analysis

SPSS software for Windows [version 23.0; IBM Corp, Armonk, NY] was used for statistical analysis. The intraexaminer agreement was evaluated with the intraclass correlation coefficient [ICC] and the Kappa index for quantitative and qualitative variables, respectively. Values greater than 0.9 were obtained for all variables.

The descriptive statistic was developed. After that the chi-square test was used to determine associations between canal shape and root morphology of the mandibular first premolars.

Finally, a logistic regression test was performed to evaluate the presence or absence of a second root canal taking into account the influence of the covariates evaluated. Significance was considered with a p -value <0.05 .

RESULTS

The baseline patient characteristics including age and sex are presented in Table 1. Of the 370 mandibular first premolars evaluated, 356 (96.2%) presented a single root and 14 had 2 roots (3.8%). In addition, 250 premolars (67.6%) had 1 root canal, while 119 (32.2%) had 2 canals and only one premolar had 3 root canals (0.3%). According to Vertucci's classification there was a higher frequency of type I premolars (n=250; 67.6%) followed by type V (n=97; 26.2%), with types III, II, IV and VIII showing the lowest frequency with 3.8%, 1.6%, 0.5% and 0.3% respectively. (Table 2).

A statistically significant association was found between the number of roots and the number of canals ($p < 0.001$), and most of the premolars with one root had one canal (70.2%) while most of the premolars with two roots had two canals (100%) (Table 3).

When evaluating the influence of age, sex and side of the dental arch on the number of root canals present in a mandibular premolar, age was found to have a significant impact ($p = 0.043$), indicating that an increase of one year in age decreased the possibility of identifying a root canal by 0.003. (Table 4).

Table 1. Baseline characteristics of the study sample.

Sex	n	Mean	Age		
			Standard Deviation	Minimum	Maximum
Male	64	42.84	15.31	18	77
Female	121	40.31	14.91	18	76
Total	185				

Table 2. Characteristics of the root morphology of the study sample.

Number of Roots	n	%
1	356	96.2
2	14	3.8
Total	370	100.0
Number of Canals	n	%
1	250	67.6
2	119	32.2
3	1	0.3
Total	370	100.0
Vertucci's classification of root canal configuration	n (Single and 2-rooted premolars)	%
I	250	67.6
II	6	1.6
III	14	3.8
IV	2	0.5
V	97	26.2
VI	0	0.0
VII	0	0.0
VIII	1	0.3
Total	370	100.0

Table 3. Association between the number of roots and the number of root canals in the study sample.

			Number of root canals			
			One	Two	Three	Total
Number of roots	One	n	250	105	1	356
		%	70.2	29.5	0.3	100.0
	Two	n	0	14	0	14
		%	0.0	100	0.0	100.0
Total	n	250	119	1	370	
	%	67.6	32.2	0.3	100.0	

$p < 0.001$, Chi-Square Test

DISCUSSION

Dentists often consider that first mandibular premolars do not present major complications in root canal treatment. However, in clinical practice the presence of more than one root in these pieces has been reported with a consequent increase in the number of canals.^{3,32} Although several studies have reported these findings in different countries,^{3,19,22} there are no reports in a Peruvian population and only few in Latin-American populations.

Diagnostic imaging is of great importance in dental practice and CBCT is an essential tool for root and canal morphology evaluations of dental pieces since a more complete and accurate examination, which determines the exact number and root configuration can be done only using CBCT.³²

In the present study 370 mandibular first premolars were evaluated, finding a higher frequency of 96.2% of single root teeth, which is similar to the majority of studies,^{1,2,4-6} and with 3.8% of teeth with 2 roots, similar to data reported by other authors,^{8,9,11} being less frequent the finding of lower first premolars with more than one root. Regarding the number of canals, in the present study the majority of premolars presented only one canal [67.6%] similar to previous studies.^{13,14,16,17}

As in previous reports,^{3,8-11} 32.2% of premolars presented two canals. Only one case representing 0.3% of the sample presented 3 canals. In this respect, one study¹³ found a frequency of three canals in premolars ranging from 0 to 2%.

Some studies,^{1-4,6,7,8} have described that genetic and racial variation can affect the anatomy and morphology of a root canal. African Americans have a higher percentage [33%] of lower first premolars with more than one canal.¹⁹ Several other studies have reported higher frequencies of additional root canals and number of roots in Chinese, Australian and sub-Saharan African populations.^{1-4,6-8,13,14} In contrast, Eurasian, Japanese and Arctic American populations had lower frequencies of the number of root canals.¹³

According to Vertucci's classification, in the present study, the majority of root canals (67.6%) presented a type I configuration. Similar studies have reported a frequency of type I configuration of 70% to 78%.^{1,3-6} The second most frequent configuration was type V with 26.2% as reported in previous studies.^{1,3-7,9} Unlike most studies, Bürklein *et al.*,¹⁰ reported a higher frequency of type V with 55.7% followed by type I with 21.9%.

Usually, the mandibular first premolars present a low frequency of more than two canals. When the two-dimensional radiographs generate doubts in relation to the presence of accessory canals, consultation with an oral and maxillofacial radiologist is recommended for in-depth study. In these cases, the use of CBCT is recommended due to its evident advantages.³⁰

The frequency of 32.2% of premolars with 2 canals should be considered during the diagnosis and treatment of these teeth. All these anatomical considerations must be considered by Latin American endodontists when treating mandibular first premolars. However, more studies on this topic must be carried out. Finally, although the voxel size can be considered a limitation of our study, we used exams from the patients' files. They were acquired with voxel size 0.256mm, exposure time 19 seconds and 180 degrees of rotation, hence low dose radiation, following ALADA principle. Future studies in similar populations using smaller fields and voxel sizes should be performed to confirm our results. Other Anatomy studies used smaller voxels and did not find a difference.^{3,4,7,9}

Finally, when we evaluated the influence of age, sex, and side of the dental arch on the number of root canals present in a mandibular first premolar, it was found that only age had a significant impact, indicating that an increase of one year with age decreased the possibility of identifying a root canal at 0.003, this situation is probably due to the greater calcification of the root canals over time, which makes their location along their trajectory more difficult. All these findings should be considered by endodontists in their clinical practice.

CONCLUSION

The presence of 1 root canal in mandibular first premolars is the most common condition, although there is a prevalence to consider with 2 root canals.

Likewise, the number of roots in the first mandibular premolars is associated with the number of canals, significantly influencing age which, with the passage of time, decreases the possibility of identifying a root canal, probably due to the greater calcification found in the root canals over the time.

CONFLICT OF INTERESTS

Authors declare no conflict of interest.

ETHICS APPROVAL

Study was approved by the Institutional Research Ethics Committee of the Universidad Científica del Sur (CIEI-CIENTÍFICA), registration code: 269-2021-POS8.

FUNDING

Authors declare no financial support.

AUTHORS' CONTRIBUTIONS

Benavides-Guzman O: Concept; Design; Funding; Materials; Literature search; Writing; Data collection and/or processing

Rodríguez-Cárdenas Y: Supervision; Critical review.

Aliaga-del Castillo A: Supervision; Critical review.

Ruíz-Mora G: Supervision; Critical review.


Arriola-Guillén LE: Supervision; Analysis and/or interpretation; Critical review

ACKNOWLEDGEMENTS


None.

ORCID


Olger Benavides-Guzman

 0000-0001-7136-6040


Yalil Rodríguez-Cárdenas

 0000-0002-3107-3013


Aron Aliaga-del Castillo

 0000-0003-3963-1742

Gustavo Ruíz-Mora

 0000-0002-9954-1047

Luis Ernesto Arriola-Guillén

 0000-0003-0010-5948

PUBLISHER'S NOTE

All statements expressed in this article are those of the authors alone and do not necessarily represent those of the publisher, editors, and reviewers.

COPYRIGHT

This is an open-access article distributed under the terms of the [Creative Commons Attribution License \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms. © 2024.



PEER REVIEW

This manuscript was evaluated by the editors of the journal and reviewed by at least two peers in a double-blind process.

PLAGIARISM SOFTWARE

This manuscript was analyzed Original by Turnitin's plagiarism detector software. Analysis report of document ID. 131622d85b55432d256f07c50d7ce29373034c25

ISSN Print 0719-2460 - ISSN Online 0719-2479.

<https://www.joralres.com/index.php/JOralRes/issue/archive>

REFERENCES.

1. Liu N, Li X, Liu N, Ye L, An J, Nie X, Liu L, Deng M. A micro-computed tomography study of the root canal morphology of the mandibular first premolar in a population from southwestern China. *Clin Oral Investig.* 2013;17(3):999-1007. <https://doi.org/10.1007/s00784-012-0778-1>. Epub 2012 Jul 10. PMID: 22777390.
2. Park JB, Kim N, Park S, Kim Y, Ko Y. Evaluation of root anatomy of permanent mandibular premolars and molars in a Korean population with cone-beam computed tomography. *Eur J Dent.* 2013;7(1):94-101. PMID: 23407684; PMCID: PMC3571516.
3. Pedemonte E, Cabrera C, Torres A, Jacobs R, Harnisch A, Ramírez V, Concha G, Briner A, Brizuela C. Root and canal morphology of mandibular premolars using cone-beam computed tomography in a Chilean and Belgian subpopulation: a cross-sectional study. *Oral Radiol.* 2018;34(2):143-150. <https://doi.org/10.1007/s11282-017-0297-5>. Epub 2017 Jul 3. PMID: 30484131.
4. Liao Q, Han JL, Xu X. [Analysis of canal morphology of mandibular first premolar]. *Shanghai Kou Qiang Yi Xue.* 2011;20(5):517-21. Chinese. PMID: 22109371.
5. Zhang D, Chen J, Lan G, Li M, An J, Wen X, Liu L, Deng M. The root canal morphology in mandibular first premolars: a comparative evaluation of cone-beam computed tomography and micro-computed tomography. *Clin Oral Investig.* 2017;21(4):1007-1012. <https://doi.org/10.1007/s00784-016-1852-x>. Epub 2016 May 13. PMID: 27178313.
6. Huang YD, Wu J, Sheu RJ, Chen MH, Chien DL, Huang YT, Huang CC, Chen YJ. Evaluation of the root and root canal systems of mandibular first premolars in northern Taiwanese patients using cone-beam computed tomography. *J Formos Med Assoc.* 2015;114(11):1129-34. <https://doi.org/10.1016/j.jfma.2014.05.008>. Epub 2014 Aug 28. PMID: 25174647.
7. Robinson S, Czerny C, Gahleitner A, Bernhart T, Kainberger FM. Dental CT evaluation of mandibular first premolar root configurations and canal variations. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2002;93(3):328-32. <https://doi.org/10.1067/moe.2002.120055>. PMID: 11925543.
8. Rahimi S, Shahi S, Yavari HR, Manafi H, Eskandarzadeh N. Root canal configuration of mandibular first and second premolars in an Iranian population. *J Dent Res Dent Clin Dent Prospects.* 2007 Summer;1(2):59-64. <https://doi.org/10.5681/joddd.2007.010>. Epub 2007 Sep 10. PMID: 23277835; PMCID: PMC3525926.
9. Walker RT. Root canal anatomy of mandibular first premolars in a southern Chinese population. *Endod Dent Traumatol.* 1988;4(5):226-8. <https://doi.org/10.1111/j.1600-9657.1988.tb00326.x>. PMID: 3248581.
10. Bürklein S, Heck R, Schäfer E. Evaluation of the Root Canal Anatomy of Maxillary and Mandibular Premolars in a Selected German Population Using Cone-beam Computed Tomographic Data. *J Endod.* 2017 ;43(9):1448-1452. <https://doi.org/10.1016/j.joen.2017.03.044>. Epub 2017 Jul 22. PMID: 28743430.
11. Awawdeh LA, Al-Qudah AA. Root form and canal morphology of mandibular premolars in a Jordanian population. *Int Endod J.* 2008;41(3):240-8. <https://doi.org/10.1111/j.1365-2591.2007.01348.x>. Epub 2007 Dec 12. PMID: 18081806.
12. Bulut DG, Kose E, Ozcan G, Sekerci AE, Canger EM, Sisman Y. Evaluation of root morphology and root canal configuration of premolars in the Turkish individuals using cone beam computed tomography. *Eur J Dent.* 2015;9(4):551-7.
13. Cleghorn BM, Christie WH, Dong CC. The root and root canal morphology of the human mandibular first premolar: a literature review. *J Endod.* 2007 ;33(5):509-16. <https://doi.org/10.1016/j.joen.2006.12.004>.
14. Alhadainy HA. Canal configuration of mandibular first premolars in an Egyptian population. *J Adv Res.* 2013;4(2):123-8. <https://doi.org/10.1016/j.jare.2012.03.002>. Epub 2012 Apr 12. PMID: 25685409; PMCID: PMC4195450.
15. Ahmad IA, Alenezi MA. Root and Root Canal Morphology of Maxillary First Premolars: A Literature Review and Clinical Considerations. *J Endod.* 2016;42 (6):861-72. <https://doi.org/10.1016/j.joen.2016.02.017>. Epub 2016 Apr 20. PMID: 27106718.
16. Martins JNR, Marques D, Silva EJNL, Caramês J, Versiani MA. Prevalence Studies on Root Canal Anatomy Using Cone-beam Computed Tomographic Imaging: A Systematic Review. *J Endod.* 2019;45(4):372-386.e4. <https://doi.org/10.1016/j.joen.2018.12.016>. Epub 2019 Mar 2. PMID: 30833097.
17. Singh S, Pawar M. Root canal morphology of South asian Indian mandibular premolar teeth. *J Endod.* 2014;40(9):1338-41. <https://doi.org/10.1016/j.joen.2014.03.021>. Epub 2014 Jul 16. PMID: 25043328.
18. Velmurugan N, Sandhya R. Root canal morphology of mandibular first premolars in an Indian population: a laboratory study. *Int Endod J.* 2009;42(1):54-8.

19. Hajihassani N, Roohi N, Madadi K, Bakhshi M, Tofangchiha M. Evaluation of Root Canal Morphology of Mandibular First and Second Premolars Using Cone Beam Computed Tomography in a Defined Group of Dental Patients in Iran. *Scientifica (Cairo)*. 2017;2017:1504341. <https://doi.org/10.1155/2017/1504341>. Epub 2017 Nov 16. PMID: 29348968; PMCID: PMC5734008.
20. Shetty A, Hegde MN, Tahiliani D, Shetty H, Bhat GT, Shetty S. A three-dimensional study of variations in root canal morphology using cone-beam computed tomography of mandibular premolars in a South Indian population. *J Clin Diagn Res*. 2014;8(8):ZC22-4.<https://doi.org/10.7860/JCDR/2014/8674.4707>. Epub 2014 Aug 20. PMID: 25302261; PMCID: PMC4190787.
21. Gu Y, Zhang Y, Liao Z. Root and canal morphology of mandibular first premolars with radicular grooves. *Arch Oral Biol*. 2013;58(11):1609-17. <https://doi.org/10.1016/j.archoralbio.2013.07.014>. Epub 2013 Aug 8. PMID: 24112726.
22. Matherne RP, Angelopoulos C, Kulild JC, Tira D. Use of cone-beam computed tomography to identify root canal systems in vitro. *J Endod*. 2008;34(1):87-9. <https://doi.org/10.1016/j.joen.2007.10.016>. PMID: 18155501.
23. Szabo BT, Pataky L, Mikusi R, Fejerdy P, Dobo-Nagy C. Comparative evaluation of cone-beam CT equipment with micro-CT in the visualization of root canal system. *Ann Ist Super Sanita*. 2012;48(1):49-52. https://doi.org/10.4415/ANN_12_01_08. PMID: 22456015.
24. Alfawaz H, Alqedairi A, Al-Dahman YH, Al-Jebaly AS, Alnassar FA, Alsubait S, Allahem Z. Evaluation of root canal morphology of mandibular premolars in a Saudi population using cone beam computed tomography: A retrospective study. *Saudi Dent J*. 2019;31(1):137-142. <https://doi.org/10.1016/j.sdentj.2018.10.005>. Epub 2018 Nov 3. PMID: 30723367; PMCID: PMC6349998.
25. Alfawaz H, Alqedairi A, Al-Dahman YH, Al-Jebaly AS, Alnassar FA, Alsubait S, Allahem Z. Evaluation of root canal morphology of mandibular premolars in a Saudi population using cone beam computed tomography: A retrospective study. *Saudi Dent J*. 2019;31(1):137-142. <https://doi.org/10.1016/j.sdentj.2018.10.005>. Epub 2018 Nov 3. PMID: 30723367; PMCID: PMC6349998.
26. Alkaabi W, AlShwaimi E, Farooq I, Goodis HE, Chogle SM. A Micro-Computed Tomography Study of the Root Canal Morphology of Mandibular First Premolars in an Emirati Population. *Med Princ Pract*. 2017;26(2):118-124. <https://doi.org/10.1159/000453039>. Epub 2016 Nov 3. PMID: 27816983; PMCID: PMC5588359.
27. Huang CC, Chang YC, Chuang MC, Lai TM, Lai JY, Lee BS, Lin CP. Evaluation of root and canal systems of mandibular first molars in Taiwanese individuals using cone-beam computed tomography. *J Formos Med Assoc*. 2010;109(4):303-8. [https://doi.org/10.1016/S0929-6646\(10\)60056-3](https://doi.org/10.1016/S0929-6646(10)60056-3). PMID: 20434040.
28. Ok E, Altunsoy M, Nur BG, Aglarci OS, Çolak M, Güngör E. A cone-beam computed tomography study of root canal morphology of maxillary and mandibular premolars in a Turkish population. *Acta Odontol Scand*. 2014;72(8):701-6. <https://doi.org/10.3109/00016357.2014.898091>. Epub 2014 May 15. PMID: 24832561.
29. Kottoor J, Albuquerque D, Velmurugan N, Kuruvilla J. Root anatomy and root canal configuration of human permanent mandibular premolars: a systematic review. *Anat Res Int*. 2013;2013:254250. <https://doi.org/10.1155/2013/254250>. Epub 2013 Dec 22. PMID: 24455268; PMCID: PMC3881342.
30. Venskutonis T, Plotino G, Juodzbaly G, Mickevičienė L. The importance of cone-beam computed tomography in the management of endodontic problems: a review of the literature. *J Endod*. 2014;40(12):1895-901. <https://doi.org/10.1016/j.joen.2014.05.009>. Epub 2014 Oct 3. PMID: 25287321.
31. Vertucci FJ. Root canal anatomy of the human permanent teeth. *Oral Surg Oral Med Oral Pathol*. 1984;58(5):589-99. [https://doi.org/10.1016/0030-4220\(84\)90085-9](https://doi.org/10.1016/0030-4220(84)90085-9). PMID: 6595621.
32. Morales-González F. Imagenological diagnosis of obliterated ducts: a review. *Rev Cient Odontol*. 2020;8(3): e038. <https://doi.org/10.21142/2523-2754-0803-2020-038>