

Original article: Variations in Root and Canal Morphology of Maxillary Premolars: A Cross-Sectional Study in Rasht, Iran



Narges Simdar¹, Farnoosh Khaksari², Sobhan Agheshteh^{3*}, Ali Rahiminezhad Kisomi^{3*}

1. Department of Endodontics, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran
2. Department of Oral & Maxillofacial Radiology, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran
3. School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran



Citation Simdar N, Khaksari F, Agheshteh S, Rahiminezhad Kisomi A. Variations in Root and Canal Morphology of Maxillary Premolars: A Cross-Sectional Study in Rasht, Iran. Journal of Dentomaxillofacial Radiology, Pathology and Surgery. 2025; 14(1): 29-36



<http://dx.doi.org/10.32592/3dj.14.1.1>

ABSTRACT



Article info:

Received: 11 Jan 2025
Accepted: 20 Feb 2025
Available Online: 09 Mar 2025

Keywords:

*Bicuspid
*Cone-Beam CT
*Endodontics

Introduction: Anatomical variations are common and can significantly impact treatment outcomes. This study aimed to investigate the prevalence of root and canal configurations in maxillary premolars and their association with age, gender, and jaw side in a specific Iranian population.

Materials and Methods: A retrospective analytical cross-sectional study analyzed CBCT images of maxillary premolars from patients treated at oral and maxillofacial radiology clinics in Rasht City, Iran, between 2021 and 2022. The number of roots and canal configurations (based on Vertucci's classification) was recorded. Statistical analysis assessed associations between these variables and age, gender, and jaw side ($\alpha = 0.05$)

Results: A total of 1,732 maxillary premolars (924 first premolars, 808 second premolars) from 759 CBCT scans were analyzed. Maxillary first premolars showed a nearly equal distribution of single-rooted (46.1%) and double-rooted (52.9%) teeth, while maxillary second premolars were predominantly single-rooted (91.1%). Vertucci types II and IV were most frequent in single-rooted maxillary first premolars, while type I predominated in second premolars. Gender significantly influenced morphology, with males having more double-rooted teeth ($P < 0.001$) and complex canal types ($P = 0.031$). Age was associated with canal configuration ($P = 0.001$), showing increased type II prevalence in older patients. No significant differences were found with the jaw side ($P > 0.05$).

Conclusions: This study provides valuable data on the root and canal morphology of maxillary premolars in a specific Iranian population. The findings highlight significant morphological variations related to tooth type, gender, and age affecting endodontic treatment planning.

1. Introduction

Successful root canal therapy (RCT) relies on complete debridement, shaping, and sealing of the entire root canal system (1). Which completely depends on a deep understanding of the anatomy of the roots and root canals (2). The anatomy of the root canal is often complex and can range from straight to curved canals, varying from simple to more intricate configurations, also with a wide variety of accessory canals and differences in the structure of the apical foramen (3). Inadequate knowledge of root anatomy can compromise treatment

outcomes and lead to difficulties in diagnosis, treatment planning, and selecting the right techniques (4).

Significant variations in root canal anatomy arise from a complex interplay of race, genetics, geographic location, gender, and age (5,6). Racial and ethnic background plays a major role, and populations from different geographic regions often display distinct prevalences of root and canal configurations, even within the same tooth type (7,8).

The wide variation in root canal configurations makes the maxillary premolars one of the most challenging teeth for

* Corresponding Authors:

Sobhan Agheshteh

Address: School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran

Tel: +981333486406

E-mail: Jafary.elham@yahoo.com

endodontic treatment compared to other teeth (9,10). The first premolars of the maxilla usually have two roots (buccal and palatal), while the second premolars are commonly single-rooted. However, variations occur, including premolars with additional roots and canals (11). It is important for clinicians to be aware of these teeth when endodontic treatments are being carried out (12).

The dental operating microscope and radiographic imaging techniques are the two primary tools used for evaluating root canal anatomy (13). The crucial role of radiography in determining root canal length has been well established (14). Later in 1996, the maxillofacial cone-beam computed tomography (CBCT) was introduced as a 3D imaging method (15). CBCT's cost-effectiveness, reduced radiation exposure, high resolution, and rapid scan time have led to its widespread adoption in various dental specialties, including endodontics (16,17). A classification system developed by Vertucci in 1984 categorizes the system of root canals into eight types, ranging from simple single canals to more complex configurations (18).

Numerous studies have explored the root and root canal morphology of maxillary premolars across diverse populations, employing classification systems to categorize canal configurations. These investigations consistently reveal significant anatomical variations related to root number, canal complexity, and accessory structures, with notable differences influenced by population, sex, and age (6,7,19–26). but they commonly faced limitations such as focusing on narrow or restricted age ranges, limiting comprehensive coverage of adult populations (26), small sample sizes, limiting statistical power, and generalizability (19,22,24), an investigation lacked strict exclusion criteria regarding restored, resorbed, or pathologically altered teeth, potentially confounding morphological assessments (6). Additionally, many studies focus heavily on maxillary first premolars with less emphasis on second premolars (7,21,23). Within Iran, Nikkardar et al. (27) analyzed a large sample from Western Iran but lacked detailed analyses of tooth side and age groups, which limited the broad application. Asheghi et al. (28) reported gender differences but had a smaller, less regionally diverse sample. Neither study excluded teeth with restorations or pathology, which may influence results (27,28).

This study aimed to determine the frequency of root and canal anatomy types in maxillary premolars using Vertucci's classification, analyzing a large sample via high-resolution CBCT scans. Strict inclusion and exclusion criteria were applied to patients referred to oral and maxillofacial radiology clinics in Rasht City between 2021 and 2022. The influence of age, gender, tooth type,

and jaw side on anatomical variations was also examined. The findings provide valuable insights to improve the accuracy of endodontic diagnosis and treatment planning in this population.

2. Materials and Methods

This retrospective analytical cross-sectional study utilized CBCT images from 759 patients who visited maxillofacial radiology clinics in Rasht City between 2021 and 2022. This study was approved by the Ethics Committee of the Guilan University of Medical Sciences (IR.GUMS.REC.1401.091).

The CBCT images, initially obtained for implant treatment planning, prosthetics, orthodontic surgery, and endodontic treatments. Using a convenience sampling method, all available images meeting the inclusion criteria during the study period were reviewed. The study sample comprised maxillary first and second premolars extracted from these images. Both right and left maxillary premolars were evaluated.

Sample size calculation was performed using the formula for estimating proportions in cross-sectional studies, based on previously reported prevalence of root canal configuration types (28). Assuming a confidence level of 95% ($Z = 1.96$) and a margin of error (d) of 0.023, the calculated minimum sample size was 1,732 maxillary premolars. Considering image availability and the applied exclusion criteria, a total of 759 patients were included in this study. Among them, 175 patients had three maxillary premolars, 214 patients had two premolars, and 253 patients had only one premolar available for evaluation. In total, 1,732 maxillary premolars were assessed using high-resolution CBCT scans according to the established inclusion and exclusion criteria. This ensured adequate statistical power and precision for estimating anatomical prevalence.

The inclusion criteria for this study encompassed patients aged between 16 and 60 years to cover a broad adult population with fully developed roots while minimizing age-related morphological changes. Only maxillary premolars with intact root morphology, exhibiting complete root formation and no history of root canal treatment, were included. Teeth that had any restorations, including fillings or crowns, regardless of their size or material, and Teeth with posts placed inside the canals were excluded to avoid any alterations in root canal anatomy. Additionally, teeth showing evidence of external or internal root resorption, periapical lesions, and root canal calcifications were excluded. any teeth with poor image

quality or artifacts that impaired the accurate evaluation of morphology were excluded (28,29).

All CBCT images were acquired using a Newtom Go device (settings: 90 kV, 15 mA, 100 x 100 mm maximum FOV, 80 µm voxel size) and evaluated using NNT Viewer software. All image assessments were conducted by a trained dental student under the supervision of an experienced oral and maxillofacial radiologist with over five years of clinical experience. To ensure reliability and accuracy of the observations, all CBCT images were independently re-evaluated by an experienced endodontist, and any discrepancies were resolved by consensus. Image analysis was performed in person using the NNT Viewer software. All observers involved in image evaluation were blinded to the patients' demographic details (age, gender, side) to minimize assessment bias. The evaluation focused on maxillary premolars to determine root number, canal count, and canal morphology. Primary assessment was conducted on axial CBCT slices progressing from the floor of the pulp chamber to the root apex. Coronal and sagittal planes were also reviewed to assist in accurate diagnosis. Teeth were divided into single-rooted, two-rooted, and three-rooted based on the number of roots. Based on the Vertucci classification, the canal morphology was divided into Vertucci types I to VIII (30).

After collecting data based on the research checklist, the data were entered into IBM SPSS v26. To determine the frequency of the root anatomy and canal morphology of the examined teeth, frequency, percentage, and 95% confidence intervals were used. The chi-square test was used to compare the frequency of canals based on the

number of roots, tooth type, age, gender, and tooth side. The level of significance of the tests was considered to be 0.05.

3. Results

A total of 1,732 maxillary premolars were analyzed from 759 CBCT images. Maxillary first premolars (n = 924, 53.35%) were slightly more frequent than maxillary second premolars (n = 808, 46.65%). The sample included 774 male and 958 female teeth, with an average patient age of 36.9 ± 13.3 years. Teeth were categorized based on the number of roots (single, double, triple) and canal morphology (Vertucci types I-VIII).

Maxillary first premolars primarily exhibited a single root (46.1%) with Vertucci type II canals. Approximately 52.9% were double-rooted, with both roots displaying Type I canals. Only 1% of teeth presented with three roots, all of which were Type I. Maxillary second premolars were predominantly single-rooted (91.1%), with Vertucci type I canals being the most common. A small proportion (8.8%) had two roots, predominantly with type I canals. A rare finding of a three-rooted second premolar, with all canals classified as Vertucci type I, was observed in a single case (0.1%). Representative CBCT images are presented in Figures 1 and 2.

Figure 3 presents a stacked bar chart summarizing the distribution of Vertucci canal types across maxillary first and second premolars. The chart highlights the predominance of Vertucci Type I canals in second premolars, accounting for the majority of configurations, followed by lower frequencies of Types II, III, and IV.

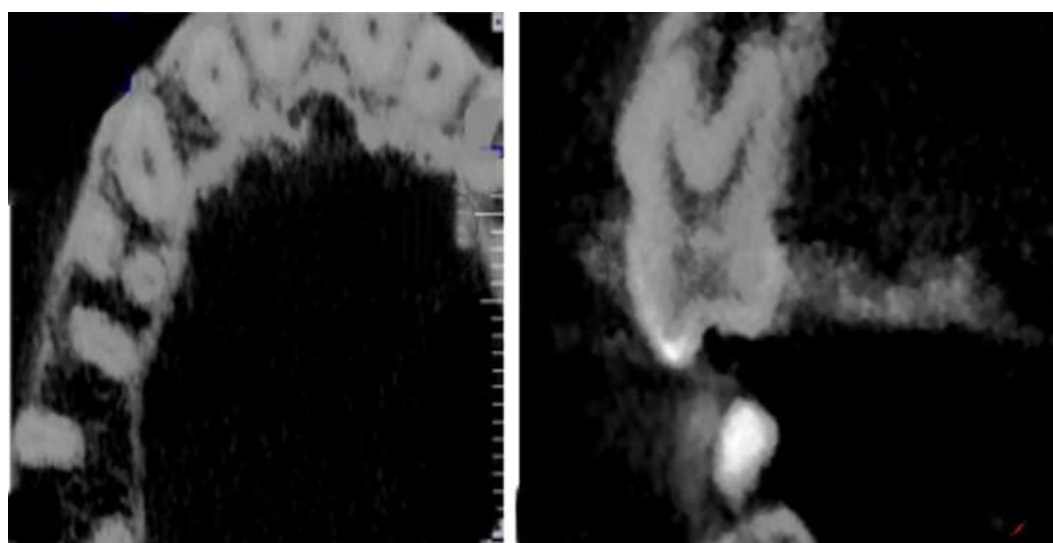


Figure 1. Double-rooted maxillary premolar in CBCT images and in axial (left) and coronal (right) views

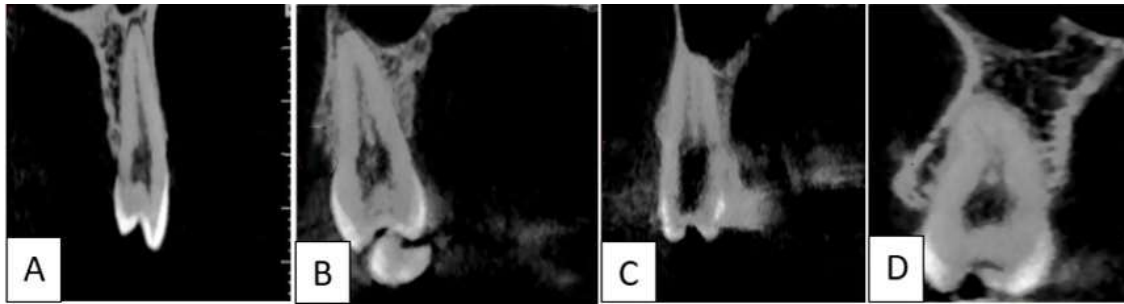


Figure 2. CBCT images of maxillary premolar; A) Type I Vertucci. B) Type II Vertucci. C) Type IV Vertucci. D) Type VI Vertucci

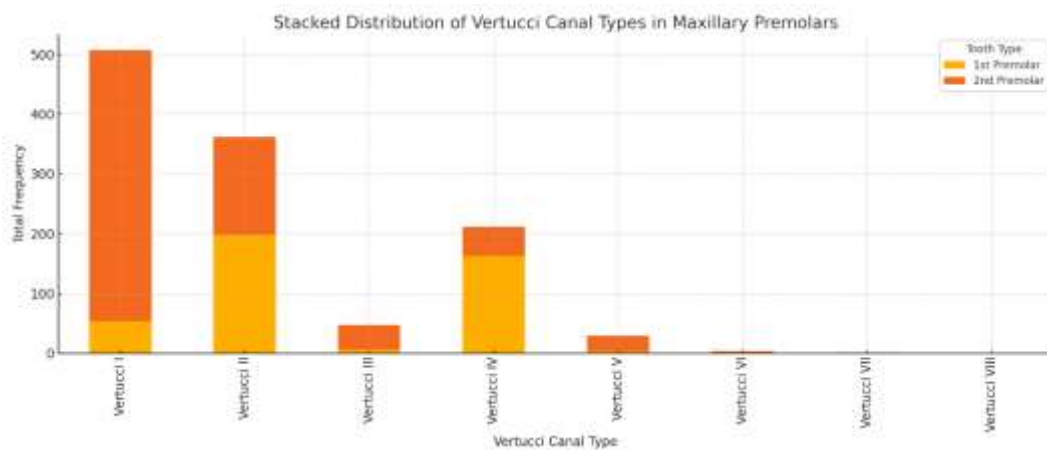


Figure 3. Root canal configuration types of maxillary premolars according to Vertucci classification

Analysis of root numbers revealed a statistically significant difference between genders ($P < 0.001$). Females showed a significantly higher prevalence of single-rooted teeth (74% vs. 58.6% in males), while males had a higher frequency of double-rooted teeth. No significant differences in root number were observed across age groups ($P = 0.453$) or between the right and left sides of the jaw ($P = 0.599$). [Table 1](#) demonstrates the distribution of root numbers by gender, age group, and jaw side, highlighting the significant gender differences and the lack of association with age or side.

Canal morphology analysis revealed a significant association between gender ($P = 0.031$) and age ($P = 0.001$). Specifically, the prevalence of Vertucci type I and IV canals decreased with age, while the frequency of type II canals increased. No significant differences in canal type were observed between jaw sides ($P = 0.576$). [Table 2](#) demonstrates the distribution of Vertucci canal types according to gender, age, and jaw side, illustrating these significant associations.

Table 1. Frequency distribution of the number of roots according to gender, age, jaw side

Variables		Number of roots			Total N (%)	P-Value ^a
		1 N (%)	2 N (%)	3 N (%)		
Gender	Male	454 (58.66)	313 (40.44)	7 (0.90)	774 (44.69)	< 0.001*
	Female	708 (73.90)	247 (25.78)	3 (0.31)	958 (55.31)	
Age	16-30	350 (65.18)	183 (34.08)	4 (0.74)	537 (31.00)	0.453
	30-50	557 (69.18)	253 (30.34)	4 (0.48)	834 (48.15)	
	50-60	235 (65.10)	124 (34.35)	2 (0.55)	361 (20.85)	
Jaw side	Right	614 (66.59)	304 (32.97)	4 (0.43)	922 (53.23)	0.599
	Left	548 (67.65)	256 (31.6)	6 (0.74)	810 (46.77)	

^a chi-square test

* "Indicates statistical significance at $p < 0.05$ ".

Table 2. Frequency distribution of the canal type (Vertucci's classification) according to gender, age, jaw side

Variables		N (%)								p-value ^a
		I	II	III	IV	V	VI	VII	VIII	
Gender	Male	496 (64.1)	171 (22.1)	17 (2.2)	78 (10.1)	9 (1.2)	3 (0.4)	0 (0.0)	0 (0.0)	0.031*
	Female	581 (60.6)	191 (19.9)	29 (3)	135 (14.1)	20 (2.1)	1 (0.1)	1 (0.1)	0 (0.0)	
Age	16-30	346 (64.4)	86 (16.0)	10 (1.9)	78 (14.5)	16 (3.0)	1 (0.2)	0 (0.0)	0 (0.0)	0.001*
	30-50	513 (61.5)	182 (21.8)	31 (3.7)	97 (11.6)	9 (1.1)	2 (0.2)	0 (0.0)	0 (0.0)	
Jaw side	50-60	218 (60.4)	94 (26.0)	5 (1.4)	38 (10.5)	4 (1.1)	1 (0.3)	1 (0.3)	0 (0.0)	0.576
	Right	572 (59.7)	201 (21.8)	20 (2.2)	112 (12.1)	15 (1.6)	1 (0.1)	1 (0.1)	0 (0.0)	
	Left	505 (62.3)	161 (19.9)	26 (3.2)	101 (12.5)	14 (1.7)	3 (0.4)	0 (0.0)	0 (0.0)	

^a chi-square test

* "Indicates statistical significance at $p < 0.05$ ".



4. Discussion

A comprehensive understanding of root morphology and canal anatomy is a prerequisite for achieving a clean and disinfected root canal during endodontic treatment. Many challenges encountered during root canal therapy can be directly attributed to an inadequate understanding of dental morphology (31). CBCT is one of the methods for evaluating root canal morphology, playing a significant role in endodontic diagnosis, treatment planning, and follow-ups (32).

This study utilized CBCT imaging to investigate the prevalence of root and canal configurations in maxillary premolars within a population of Rasht City, Iran, and to explore the influence of age, gender, and jaw side.

Maxillary first premolars in our sample exhibited a prevalence of single roots (46.1%), closely mirroring findings by Mashyakh (33), and Al-Zubaidi et al. (2). However, this contrasts with studies reporting higher proportions of single-rooted teeth (9,28,34), potentially reflecting ethnic or geographic variations. The higher prevalence of double-rooted teeth (52.9%) in our cohort aligns with Loh's observations (35). However, it differs from some studies that report a different distribution (2).

For maxillary second premolars, the overwhelming predominance of single roots (91.1%) is consistent with several studies (28,33,36), but other reports show a substantially higher frequency of two-rooted teeth (29,37,38). These discrepancies likely stem from variations in sample populations, methodologies, and potentially genetic influences.

In single-rooted maxillary first premolars, Vertucci types II, IV, and I were most prevalent (46.5%, 38.3%, and 12.7%, respectively), broadly consistent with Asheghi et al. (28), and Popovic et al. (38). Nevertheless, diverging from others shows a higher prevalence of type I (37), or different rank orders (9,39,40). The absence of types VII and VIII mirrors many studies, suggesting these are rare configurations. Double- and triple-rooted teeth predominantly showed type I canals in buccal and palatal

roots, a pattern observed in other studies. In maxillary second premolars, the prevalence of types I, II, and IV in single-rooted teeth was high and aligned with several studies (2,28,37,38,40,41), but not all (42,43). These discrepancies underscore the heterogeneity of canal morphology across diverse populations.

Our findings reveal a statistically significant association between gender, root number, and canal configuration. Males showed a higher prevalence of multiple-rooted teeth and complex canal configurations, while females demonstrated a higher frequency of single-rooted teeth. This is consistent with some studies (44,45), but contrasts with others, who found no gender association (12). This divergence suggests that the influence of gender on root morphology may be population-specific and warrants further investigation.

While the number of roots remained relatively consistent across age groups, a statistically significant age-related variation in Vertucci types emerged. Specifically, a decrease in type I and IV configurations and an increase in type II configurations were observed with advancing age, consistent with some studies (25,46), but not others (29,47). These changes may be attributed to developmental processes, hormonal fluctuations, dietary factors, mechanical stresses, or genetic predispositions, necessitating further research to elucidate the mechanisms fully.

No statistically significant differences were observed in root number or Vertucci-type distribution between the right and left sides of the jaw. This aligns with most studies (12,33,44), suggesting systemic factors may be more influential in determining root canal configurations than local variations. However, this contradicts some findings reporting laterality differences (48), potentially due to population-specific factors.

These findings highlight the critical need for determining root and canal morphology, especially in maxillary premolars, where anatomical variation is common. Awareness of age- and gender-related differences can guide clinicians in anticipating complexity and adapting

treatment plans. For instance, older patients often require more meticulous canal scouting. Additionally, male patients' tendency toward multi-rooted premolars warrants heightened diagnostic scrutiny to prevent missed canals and ensure treatment success.

Despite the valuable insights provided by this study, several limitations should be acknowledged. First, the retrospective nature of CBCT image selection may introduce sampling bias, as most of the images were obtained initially for clinical purposes unrelated to endodontic evaluation. Second, the study was confined to a single geographic region, potentially limiting the generalizability of the findings to broader populations with different ethnic and genetic backgrounds. Additionally, although CBCT offers high-resolution imaging, the interpretation of canal configurations remains partially operator-dependent and subject to inter-observer variability.

Future studies should include larger and more diverse populations across multiple regions to validate and expand upon these findings. Incorporating advanced machine learning algorithms for image analysis could also enhance the objectivity and reproducibility of morphological assessments. Moreover, prospective studies evaluating clinical outcomes about anatomical complexity would further elucidate the clinical relevance of canal morphology variations and support the development of predictive models for treatment planning.

5. Conclusions

This cross-sectional analysis offers a comprehensive anatomical assessment of maxillary premolars in an Iranian subpopulation using CBCT imaging. The study confirms substantial morphological variability, with maxillary first premolars exhibiting a nearly equal distribution of single and double roots and maxillary second premolars predominantly presenting a single-rooted configuration. Canal morphology patterns, particularly the predominance of Vertucci types II and IV in first premolars and type I in second premolars, were

significantly associated with gender and age. These findings underscore the necessity for individualized preoperative assessment to optimize endodontic treatment strategies.

Ethical Considerations

This study was conducted in accordance with the ethical standards of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of Guilan University of Medical Sciences (Approval code: IR.GUMS.REC.1401.091). Informed consent was obtained from all participants or their legal guardians prior to inclusion in the study.

Funding

None.

Authors' Contributions

Narges Simdar Conceptualization, Methodology, Formal Analysis **Farnoosh Khaksari** Methodology, Data Curation **Sobhan Agheshteh** Supervision, Writing-Review and Editing **Ali Rahiminezhad Kisomi** Investigation, Visualization, Writing-Original draft.

Conflict of Interests

The authors declare that they have no conflicts of interest relevant to this study.

Availability of data and material

The datasets generated and/or analyzed during the current study are available from the corresponding authors on reasonable request.

Acknowledgments

We extend our sincere gratitude to Rasht City's oral and maxillofacial radiology clinics for their generous assistance with this study. Their expertise and support in data collection were invaluable.

References

1. Karobari MI, Ahmed HMA, Khamis MF Bin, Ibrahim N, Noorani TY. Application of two systems to classify the root and canal morphology in the human dentition: A national survey in India. *J Dent Educ*. 2023;87(8):1089–98. [\[DOI:10.1002/jdd.13236\]](https://doi.org/10.1002/jdd.13236)
2. Al-Zubaidi SM, Almansour MI, Al Mansour NN, Alshammari AS, Alshammari AF, Altamimi YS, et al. Assessment of root morphology and canal configuration of maxillary premolars in a Saudi subpopulation: a cone-beam computed tomographic study. *BMC Oral Health*. 2021 Aug;21(1):397. [\[DOI: 10.1186/s12903-021-01739-1\]](https://doi.org/10.1186/s12903-021-01739-1)
3. Navas JM, Doranala S, Khushnud A, Sinha J, Jadhav AA, Gudapati S, et al. Evaluation of the Root Canal Morphology of Human Teeth by Cone Beam Computed Tomography and Micro-Computed Tomographic-A Systematic Review with Meta-analysis. *J Pharm Bioallied Sci*. 2022 Jul;14(Suppl 1):S254–9. [\[DOI: 10.4103/jpbs.jpbs.714.21\]](https://doi.org/10.4103/jpbs.jpbs.714.21)
4. Karobari MI, Iqbal A, Syed J, Batul R, Adil AH, Khawaji SA, et al. Evaluation of root and canal morphology of mandibular premolar amongst Saudi subpopulation using the new system of classification: a CBCT study. *BMC Oral Health*. 2023 May;23(1):291. [\[DOI: 10.1186/s12903-023-03002-1\]](https://doi.org/10.1186/s12903-023-03002-1)
5. Chaple Gil AM, Santiesteban Velázquez M, Afrashtehfar KI. Geographic patterns of the number of root canals in permanent molars. A Systematic Review. *medRxiv*. 2024 Jan 1;2024.06.08.24308647. [\[DOI: 10.1101/2024.06.08.24308647\]](https://doi.org/10.1101/2024.06.08.24308647)
6. Aljawhar AM, Ibrahim N, Abdul Aziz A, Ahmed HMA, Azami

- NH. Micro-computed tomographic evaluation of root and canal anatomy of maxillary first premolars in Iraqi sub-population. *Sci Rep.* 2025 Mar;15(1):10821. [\[Link\]](#)
7. Martins JNR, Tummala S, Nallapati S, Marques D, Silva EJNL, Caramês J, et al. Population-Specific Anatomical Variations in Premolar Root Canal Systems: A Cross-Sectional Cone-Beam Computed Tomography Study of Jamaican and Portuguese Subpopulations. *Dent J.* 2025 Jan;13(2). [\[DOI: 10.3390/dj13020050\]](#)
8. Haddadi A, Hoshyari N, Abbaspour H, Hossein Nataj A, Keshvari A. Prevalence of the C-shaped root canal morphology in the Iranian population: a systematic review and meta-analysis. *J Res Dent Maxillofac Sci.* 2024 Jun 1;9(2):132-43. [\[DOI: 10.61186/jrdms.9.2.132\]](#)
9. Liu X, Gao M, Ruan J, Lu Q. Root canal anatomy of maxillary first premolar by microscopic computed tomography in a chinese adolescent subpopulation. *Biomed Res Int.* 2019 Nov 16;2019:1-9. [\[DOI: 10.1155/2019/4327046\]](#)
10. Karobari MI, Noorani TY, Halim MS, Ahmed HMA. Root and canal morphology of the anterior permanent dentition in Malaysian population using two classification systems: a CBCT clinical study. *Aust Endod J.* 2021;47(2):202-16. [\[DOI: 10.1111/aej.12454\]](#)
11. Versiani MA, Pereira MR, Pécora JD, Sousa-Neto MD. Root canal anatomy of maxillary and mandibular teeth. The root canal anatomy in permanent dentition. Springer; 2018. p. 181-239. [\[Link\]](#)
12. Olczak K, Pawlicka H, Szymański W. Root form and canal anatomy of maxillary first premolars: a cone-beam computed tomography study. *Odontology.* 2022 Apr;110(2):365-75. [\[DOI: 10.1007/s10266-021-00670-9\]](#) [\[PMID: 34714481\]](#)
13. Ahmed HMA. A critical analysis of laboratory and clinical research methods to study root and canal anatomy. *Int Endod J.* 2022 Apr;55 Suppl 2:229-80. [\[DOI: 10.1111/iej.13702\]](#)
14. Jacobsohn PH, Fedran RJ. Making darkness visible: the discovery of X-ray and its introduction to dentistry. *J Am Dent Assoc.* 1995 Oct;126(10):1359-67. [\[DOI: 10.14219/jada.archive.1995.0044\]](#)
15. Scarfe WC, Levin MD, Gane D, Farman AG. Use of cone beam computed tomography in endodontics. *Int J Dent.* 2009;2009:634567. [\[DOI: 10.1155/2009/634567\]](#)
16. Mallya S, Lam E. White and Pharoah's Oral Radiology: Principles and Interpretation [Internet]. Mosby; 2018. [\[Link\]](#)
17. Venkatesh E, Elluru SV. Cone beam computed tomography: basics and applications in dentistry. *J Istanbul Univ Fac Dent.* 2017;51(3 Suppl 1):S102-21. [\[Link\]](#)
18. Vertucci FJ. Root canal anatomy of the human permanent teeth. *Oral Surg Oral Med Oral Pathol.* 1984 Nov;58(5):589-99. [\[DOI: 10.1016/0030-4220\(84\)90085-9\]](#) [\[PMID: 6595621\]](#)
19. Kartik SN, Shetty K, Vergis BA, Natarajan S, D'Souza JL. Analysis of root morphology and internal anatomy of 400 maxillary first premolars using cone-beam computed tomography in an Indian Dravidian subpopulation: An ex vivo study. *J Conserv Dent.* 2022;25(5):487-91. [\[DOI: 10.4103/jcd.jcd_158_22\]](#) [\[PMID: 36506628\]](#)
20. Khanna S, Jobanputra L, Mehta J, Parmar A, Panchal A, Mehta F. Revisiting premolars using cone-beam computed tomography analysis and classifying their roots and root canal morphology using newer classification. *Cureus.* 2023 May;15(5):e38623. [\[DOI:10.7759/cureus.38623\]](#) [\[PMID: 37284378\]](#)
21. Mirza MB. Evaluating the internal anatomy of maxillary premolars in an adult saudi subpopulation using 2 classifications: a cbct-based retrospective study. *Med Sci Monit.* 2024 Mar;30:e943455. [\[DOI: 10.12659/MSM.943455\]](#) [\[PMID: 38489240\]](#)
22. Yanqui-Gómez JS, Dulanto-Vargas JA, Carranza-Samanez KM. Morphology of roots and canals of maxillary first premolars: a cbct study in a peruvian sample. *Int J Dent.* 2024;2024:2341041. [\[DOI: 10.1155/2024/2341041\]](#) [\[PMID: 39380790\]](#)
23. Jung YH, Hwang JJ, Lee JS, Cho BH. Analysis of root number and canal morphology of maxillary premolars using cone-beam computed tomography. *Imaging Sci Dent.* 2024 Dec;54(4):370-80. [\[DOI: 10.5624/isd.20240150\]](#) [\[PMID: 39744553\]](#)
24. Al-Sayaghi AM, Madfa AA, Mufadhal AA, Al-Shami IZ, Al-Shami AM. Roots form and canals morphology of maxillary second premolar in a sample of yemeni population. *Int J Dent.* 2025;2025:3380604. [\[DOI: 10.1155/ijod/3380604\]](#) [\[PMID: 40223865\]](#)
25. Watanabe S, Yabumoto S, Okiji T. Evaluation of root and root canal morphology in maxillary premolar teeth: A cone-beam computed tomography study using two classification systems in a Japanese population. *J Dent Sci.* 2025 Apr;20(2):927-35. [\[DOI: 10.1016/j.jds.2024.08.024\]](#) [\[PMID: 40224074\]](#)
26. Pertek Hatipoğlu F, Magat G, Karobari MI, Madarati AA, Tulegenova I, Hatipoğlu Ö, et al. Root and canal configurations of maxillary first premolars in 22 countries using two classification systems: a multinational cross-sectional study. *Sci Rep.* 2025 Jun;15(1):19290. [\[DOI: 10.1038/s41598-025-02669-6\]](#) [\[PMID: 40456872\]](#)
27. Nikkardar N, Asnaashari M, Karimi A, Araghi S, Seifitabar S, Golshah A. Root and canal morphology of maxillary teeth in an Iranian subpopulation residing in western iran using cone-beam computed tomography. *Iran Endod J.* 2020;15(1):31-7. [\[DOI: 10.22037/iej.v15i1.25386\]](#) [\[PMID: 36704317\]](#)
28. Asheghi B, Momtahan N, Sahebi S, Zangoie Booshehri M. Morphological evaluation of maxillary premolar canals in Iranian population: a cone-beam computed tomography study. *J Dent (Shiraz, Iran).* 2020 Sep;21(3):215-24. [\[DOI: 10.30476/DENTJODS.2020.82299.1011\]](#) [\[PMID: 33062816\]](#)
29. Karobari MI, Iqbal A, Batul R, Adil AH, Syed J, Algarni HA, et al. Exploring age and gender variations in root canal morphology of maxillary premolars in Saudi sub population: a cross-sectional CBCT study. *BMC Oral Health.* 2024 May;24(1):543. [\[DOI: 10.1186/s12903-024-04310-w\]](#) [\[PMID: 38724952\]](#)
30. Vertucci F, Seelig A, Gillis R. Root canal morphology of the human maxillary second premolar. *Oral Surg Oral Med Oral Pathol.* 1974 Sep;38(3):456-64. [\[DOI: 10.1016/0030-4220\(74\)90374-0\]](#) [\[PMID: 4528716\]](#)
31. Mustafa M, Karobari MI, Al-Maqtari AAA, Abdulwahed A, Almokhatieb AA, Almufleh LS, et al. Investigating root and canal morphology of anterior and premolar teeth using CBCT with a novel coding classification system in Saudi subpopulation. *Sci Rep.* 2025;15(1):4392. [\[DOI: 10.1038/s41598-025-86277-4\]](#)
32. Rahmati A, Khoshbin E, Shokri A, Yalfani H. Cone-beam computed tomography assessment of the root canal morphology of primary molars. *BMC Oral Health.* 2023 Sep;23(1):692. [\[DOI: 10.1186/s12903-023-03414-z\]](#) [\[PMID: 37749546\]](#)
33. Mashyakh M. Anatomical evaluation of maxillary premolars in a Saudi population: an *in vivo* cone-beam computed tomography study. *J Contemp Dent Pract.* 2021 Mar;22(3):284-9. [\[PMID: 34210930\]](#)
34. Kfir A, Mostinsky O, Elyzur O, Hertzeanu M, Metzger Z, Pawar AM. Root canal configuration and root wall thickness of first maxillary premolars in an Israeli population. A Cone-beam computed tomography study. *Sci Rep.* 2020 Jan;10(1):434. [\[DOI: 10.1038/s41598-019-56957-z\]](#) [\[PMID: 31949190\]](#)
35. Loh HS. Root morphology of the maxillary first premolar in Singaporeans. *Aust Dent J.* 1998 Dec;43(6):399-402. [\[DOI: 10.1111/j.1834-7819.1998.tb00199.x\]](#) [\[PMID: 9973709\]](#)
36. Mohamed Kamel S, Al Moghazy HH, Kamal M, Loui K, Aysar M, Fayed S. Root and root canal morphology of permanent maxillary premolars in a selected sample of egyptian

- population: an anatomical and anthropological study. MSA Dent J. 2025;4(2):10–6. [[10.21608/msadj.2025.368548.1049](https://doi.org/10.21608/msadj.2025.368548.1049)]
37. Nazeer MR, Khan FR, Ghafoor R. Evaluation of root morphology and canal configuration of Maxillary Premolars in a sample of Pakistani population by using Cone Beam Computed Tomography. JPMA J Pakistan Med Assoc. 2018 Mar;68(3):423–7. [[PMID: 29540878](https://pubmed.ncbi.nlm.nih.gov/29540878/)]
 38. Popovic M, Papić M, Acovic A, Zivanovic S, Kanjevac T. Cone-beam computed tomography study of root number and root canal configuration of premolars in Serbian population. Med Pregl. 2018 Jan 1;71:100–7. [[DOI: 10.2298/MPNS1804100P](https://doi.org/10.2298/MPNS1804100P)]
 39. ELKady A, Allouba K. Cone beam computed tomographic analysis of root and canal morphology of maxillary premolars in Saudi subpopulation. Dent J. 2013 Jul 1;59:3419. [[Link](#)]
 40. Celikten B, Orhan K, Aksoy U, Tufenkci P, Kalender A, Basmaci F, et al. Cone-beam CT evaluation of root canal morphology of maxillary and mandibular premolars in a Turkish Cypriot population. BDJ open. 2016;2:15006. [[DOI: 10.1038/bdjopen.2015.6](https://doi.org/10.1038/bdjopen.2015.6)] [[PMID: 29607060](https://pubmed.ncbi.nlm.nih.gov/29607060/)]
 41. Alqedairi A, Alfawaz H, Al-Dahman Y, Alnassar F, Al-Jebaly A, Alsubait S. Cone-Beam Computed Tomographic Evaluation of Root Canal Morphology of Maxillary Premolars in a Saudi Population. Biomed Res Int. 2018;2018:8170620. [[DOI: 10.1155/2018/8170620](https://doi.org/10.1155/2018/8170620)] [[PMID: 30186867](https://pubmed.ncbi.nlm.nih.gov/30186867/)]
 42. Namdar P, Molania T, Hoshyari N, Lotfizadeh A, Alimohammadi M, Khojastehfar M, et al. Evaluation of Root and Canal Morphology of Maxillary First and Second Molars by Cone Beam Computed Tomography in a Northern Iranian Population TT -. J-Res-Dent-Maxillofac-Sci [Internet]. 2023 Nov 1;8(4):265–73. [[Link](#)]
 43. Asiri AA, AlQahtani KW, Tarrosh MY, Shaiban AS, Al Shawkani HA, Alaajam WH, et al. Root morphology and canal configuration of permanent canines among Saudi population: systematic review and comparison with worldwide studies. Int J Gen Med. 2022;15:6849. [[DOI: 10.2147/IJGM.S380084](https://doi.org/10.2147/IJGM.S380084)] [[PMID: 36061964](https://pubmed.ncbi.nlm.nih.gov/36061964/)]
 44. Pan JYY, Parolia A, Chuah SR, Bhatia S, Mutalik S, Pau A. Root canal morphology of permanent teeth in a Malaysian subpopulation using cone-beam computed tomography. BMC Oral Health. 2019;19(1):14. [[DOI: 10.1186/s12903-019-0710-z](https://doi.org/10.1186/s12903-019-0710-z)] [[PMID: 30642318](https://pubmed.ncbi.nlm.nih.gov/30642318/)]
 45. Syed GA, Pullishery F, Alhazmi KA, Nazer MI, Alkhamis A, Meer FMS, et al. CBCT evaluation of root canal morphology of maxillary first premolar in Saudi subpopulation. J Pharm Bioallied Sci. 2024 Apr;16 (Suppl 2):S1619–22. [[DOI: 10.4103/jpbs.jpbs_1048_23](https://doi.org/10.4103/jpbs.jpbs_1048_23)] [[PMID: 38882762](https://pubmed.ncbi.nlm.nih.gov/38882762/)]
 46. Solomonov M, Kim HC, Hadad A, Levy DH, Ben Itzhak J, Levinson O, et al. Age-dependent root canal instrumentation techniques: a comprehensive narrative review. Restor Dent Endod. 2020 May;45(2):e21. [[DOI: 10.5395/rde.2020.45.e21](https://doi.org/10.5395/rde.2020.45.e21)] [[PMID: 32483538](https://pubmed.ncbi.nlm.nih.gov/32483538/)]
 47. Aslam N, Asif M, Nadeem A, Qureshi A, Tayyaba S, Mahmood T. Radiographic and clinical assessment of two canals in the maxillary second premolar. J Ayub Med Coll Abbottabad , JAMC. 2021;33(Suppl 1(4):S734–7. [[PMID: 35077618](https://pubmed.ncbi.nlm.nih.gov/35077618/)]
 48. 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 Nov;72(8):701–6. [[DOI: 10.3109/00016357.2014.898091](https://doi.org/10.3109/00016357.2014.898091)] [[PMID: 24832561](https://pubmed.ncbi.nlm.nih.gov/24832561/)]