ORIGINAL RESEARCH

Evaluation of Root Canal Morphology of Maxillary Second Premolars and Its Relation to Maxillary Sinus in a Saudi Arabian Population

Hemant Ramesh Chourasia[1], Ali I Odabi[2], Alhassan A Owis[3], Zarah A Dahas[4], Ahmed M Bokhari[5], Mohammed Mashyakhy[6], Ahmad H Jabali[7]

Abstract

Aim: This study aimed to evaluate the root canal anatomy of maxillary second premolars, and its relation to the maxillary sinus in a Saudi Arabian population using cone-beam computed tomography.

Materials and methods: Records of 301 patients (602 Teeth) were obtained from a Cone-beam Computed Tomography Database of the College of Dentistry, Jazan University from February 2020 to January 2022. The number of roots, root canals, and the relationship between the root apices of maxillary second premolars and the floor of the maxillary sinuses were studied. The data was recorded, tabulated, and statistically analyzed.

Results: A majority of maxillary second premolars were single-rooted (78.74%), followed by double-rooted (20.76%) and three-rooted (0.5%). Two canals (59.1%) were seen in the majority of the examined teeth, followed by one canal (40.4%) and three canals (0.5%). The roots of the maxillary second premolars were predominantly (69.17%) outside the sinus. Nineteen percent of roots were in contact with the floor of the maxillary sinus with no significant difference between buccal and palatal roots, and around twelve percent (11.73%) of roots were inside the maxillary sinus.

Conclusions: The root canal system morphology of maxillary second premolars showed a wide range of anatomical variations in the Saudi Arabian population with a predominance of single roots. Most of the roots were located outside the sinus followed by in contact and then inside the sinus. Three-rooted second premolars were exceedingly rare.

Clinical significance: The cognizance of maxillary second premolar root canal anatomy and its relation to maxillary sinus would be a valuable affirmation for dentists of different nationalities treating the Saudi Arabian population to ensure a successful endodontic treatment.

Keywords: Cone-beam computed tomography, Endodontics, Maxillary premolars, Maxillary sinus, Morphology, Root canal.

The Journal of Contemporary Dental Practice (2023): 10.5005/jp-journals-10024-3456

Introduction

Endodontic treatment success is predicated on the accurate shaping, disinfecting, and filling of the root canal.[1] Adequate debridement and complete obturation in three dimensions require precise knowledge regarding anatomical variations that may present in various populations. Anatomical variations include isthmuses, deltas, or the number of canals.[2] Infection in tortuous and complex anatomical portals is related to the etiology of nonsurgical root canal treatment failures.[3] Missed root canals are a common cause of endodontic treatment failure.[4,5]

Maxillary second premolars frequently require endodontic treatment.[6] Typically, maxillary second premolars present with a single root and an oval-shaped canal.[7] Less frequently, second premolars have two roots, each with a separate root canal.[8] Although two canals within a single root may also be found. The prevalence of dual canals at the apical region of the tooth is around 4–50%.[9–11] Several studies report a great degree of variability in the maxillary second premolars with rare findings of third canals.[12,13] The exact reason for the formation of multiple canals remains unclear but is thought to be a result of injuries to Hertwig's epithelial root sheath during development and genetics.[14]

Genetics and ethnicity are agents of variation in root canal morphology.[15–18] Examining a specific ethnic group can contribute to the understanding of existing root canal variations. The two-rooted configuration in maxillary second premolars is uncommon, varying among various ethnicities. Studies have found double-rooted maxillary second premolars in varying frequencies in different populations Indian (35%), Egyptian (26%), Turkish (50.64%), and Spanish (15.5%).[19–22] A Brazilian population had two root canals at the apex of the maxillary second premolar (32.4%) and three roots (0.3%).[8] The three-rooted configuration has been found to be approximately 2%.[23] Several questions regarding the number

[1,6,7]Department of Restorative Dental Sciences, College of Dentistry, Jazan University, Saudi Arabia

[2]Dental Department, Sabya General Hospital, Ministry of Health, Jazan, Saudi Arabia

[3]Resident in Endodontic, King Abdulaziz University Dental Hospital, Saudi Arabia

[4]Resident in Endodontic, King Faisal Specialist Hospital & Research Centre, Saudi Arabia

[5]Department of Preventive Dental Sciences, College of Dentistry, Jazan University, Saudi Arabia

Corresponding Author: Hemant Ramesh Chourasia, Department of Restorative Dental Sciences, College of Dentistry, Jazan University, Saudi Arabia, Phone: +966509795107, e-mail: hchourasia@jazanu.edu.sa

How to cite this article: Chourasia HR, Odabi AI, Owis AA, *et al*. Evaluation of Root Canal Morphology of Maxillary Second Premolars and its Relation to Maxillary Sinus in a Saudi Arabian Population. J Contemp Dent Pract 2023;24(1):35–41.

Source of support: Nil

Conflict of interest: None

and variation in root canal geometry remain unresolved. This knowledge can facilitate endodontic treatment in second premolars which poses a unique challenge to endodontists with its variability among populations.

The proximity of the posterior teeth close to the maxillary sinus can complicate matters when endodontic treatment is indicated.[24,25] An inflammatory response may involve the sinus mucosa when the root apices are close to the maxillary sinus. With endodontic instrumentation, there is a risk of instruments or endodontic materials escaping the confines of the root canal. Extrusion of debris beyond the apical foramen can lead to periapical inflammation and postoperative pain. Maxillary sinusitis of endodontic origin is a possibility in approximately 60% of maxillary posterior teeth with infections.[26] Failure to identify and manage a pathology with an endodontic origin can result in the persistence of sinus disease.[27] A detailed analysis of the topographic relationship between the root canals of the maxillary second premolar and the maxillary sinus would be of immense value in endodontic treatment planning.

Investigating the anatomy of root canals can be performed in different ways. This includes sectioning, tooth-clearing, radiographic examination, micro-computed tomography (micro-CT), and cone beam computed tomography (CBCT).[28,29] Conventional radiography is limited by its nature that is a two-dimensional image representing a three-dimensional structure. Neelakantan et al. tested different methods of identifying root canal structures and reported that the accuracy of CBCT can be comparable to tooth-clearing techniques and canal staining.[30] Utilizing the micro-CT in root canal identification is optimum. However, its usage is limited by its high cost, high radiation dosage, and accessibility in certain countries.[31] Therefore, the present study used cone-beam computed tomography to evaluate the root canal anatomy of maxillary second premolars and its relation to the maxillary sinus in the Saudi Arabian population.

Materials and Methods

This study protocol was approved by the Ethics Committee of the Scientific Research Unit, College of Dentistry, Jazan University, Saudi Arabia (Reference number: CODJU-1814S). The sample for this retrospective cross-sectional study included the radiographic records of 301 walk-in Saudi patients (age range 16–72 years) who came for dental care visits at the College of Dentistry, Jazan University from February 2020 to January 2022. Data obtained included the Saudi national identity card number, age, and gender of the patients. All the patients had given informed consent before undergoing any radiographic imaging. The CBCT images were taken according to a standardized protocol. All the radiographs followed the manufacturer's safety protocols, which guaranteed limited exposure for the patients. Images were taken in axial, coronal, and cross-sectional angles in order to provide all possible views of the root canal anatomical structures. Cone beam computed tomography (CBCT) images were taken using the 3D Accuitomo 170 (MORITA, Japan) operated at 50–90 kVp and 2–10 mA, with a field of view (FOV) of 50 mm × 50 mm, an exposure time of 15–24 seconds, and a voxel size of 120 µm. Two general dentists under the supervision of three endodontists evaluated all of the CBCT images.

The CBCT images were collected from the central university patients' records. All maxillary second premolar imagery was included in the study, except for teeth with apical periodontitis, those that had been endodontically treated or restored with a post, core, and immature apices were excluded. Cases, where the canal anatomy was obscured by physiological or pathological processes, were also excluded.

All CBCT images were evaluated retrospectively. The examiner evaluated each image twice, with a one-week period interval between each evaluation. A preview of the three planes was first assessed, followed by visualization. The evaluation focused on the following points:

- The number of roots: The presence of one, two, or three rooted maxillary second premolar
- The number of canals: The presence of one, two, or three root canals in the maxillary second premolar, and
- The relationship between roots and maxillary sinus: The presence of root apices of the maxillary second premolar outside or inside the maxillary sinus, or in contact with the maxillary sinus.

The recorded data were collected, tabulated, and statistically analyzed using SPSS software for Windows version 21.0 (SPSS Inc., Chicago, IL, USA). The number of roots, the number of canals within each root, and root and root canal variants were calculated. A chi-square test and Fisher's exact test were used to determine the significant differences in the study parameters. All mentioned tests were considered statistically significant at a *p*-value less than 0.05.

Results

Number of Roots

A majority of the patients had maxillary second premolars with a single root. Four hundred and seventy-four of 602 maxillary second premolars were single rooted (78.74%), while 125 of 602 maxillary second premolars were double rooted (20.76%), and only three premolars (0.5%) had three separate roots (Fig. 1 and Table 1).

Number of Canals

A majority of the maxillary second premolars examined had two canals. Two canals were found in 356 of 602 teeth (59.1%), one root canal in 243 of 602 teeth (40.4%), and only three premolars had three canals (0.5%) (Fig. 1). There was a significant correlation between the number of roots and the number of canals (Table 1).

Relationship between Roots and Maxillary Sinus

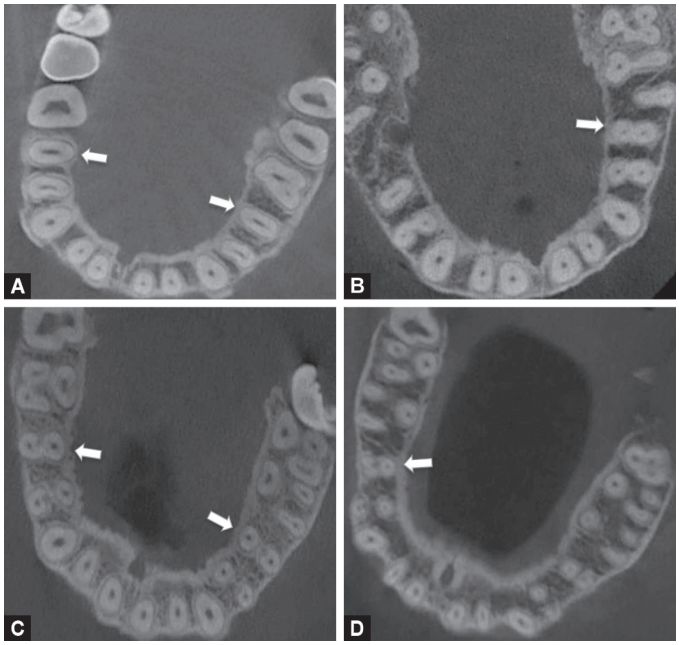
The roots of the maxillary second premolars were predominantly outside the sinus (69.17%), followed by roots in contact with the floor of the maxillary sinus (19.1%) with no significant difference between buccal and palatal roots, and roots inside the maxillary sinus (11.73%) (Fig. 2). There was no difference in terms of root location (Table 2).

The majority of single-rooted teeth had one canal (40.20%) ($p < 0.05$). Thirty-eight and a half percent of the single-rooted teeth had two canals ($p < 0.05$).

The odds to find roots outside the sinus reduce with age right side OR = 0.916, *p*-value < 0001, and left side = 0.953, *p*-value = 0.007 (Table 3).

There are fewer odds to find right-sided palatal roots away from (OR = 0.002) ($p < 0.0001$) or in contact with the sinus (OR = 0.079) ($p = 0.01$). Similarly applies to the left-sided palatal roots: A way (OR = 0.00002) ($p < 0.0001$), in contact (OR = 0.006) ($p = 0.001$). There are fewer odds of finding two canalled right-sided teeth to be away from the sinus (OR = 0.021) ($p = 0.019$) (Table 4).

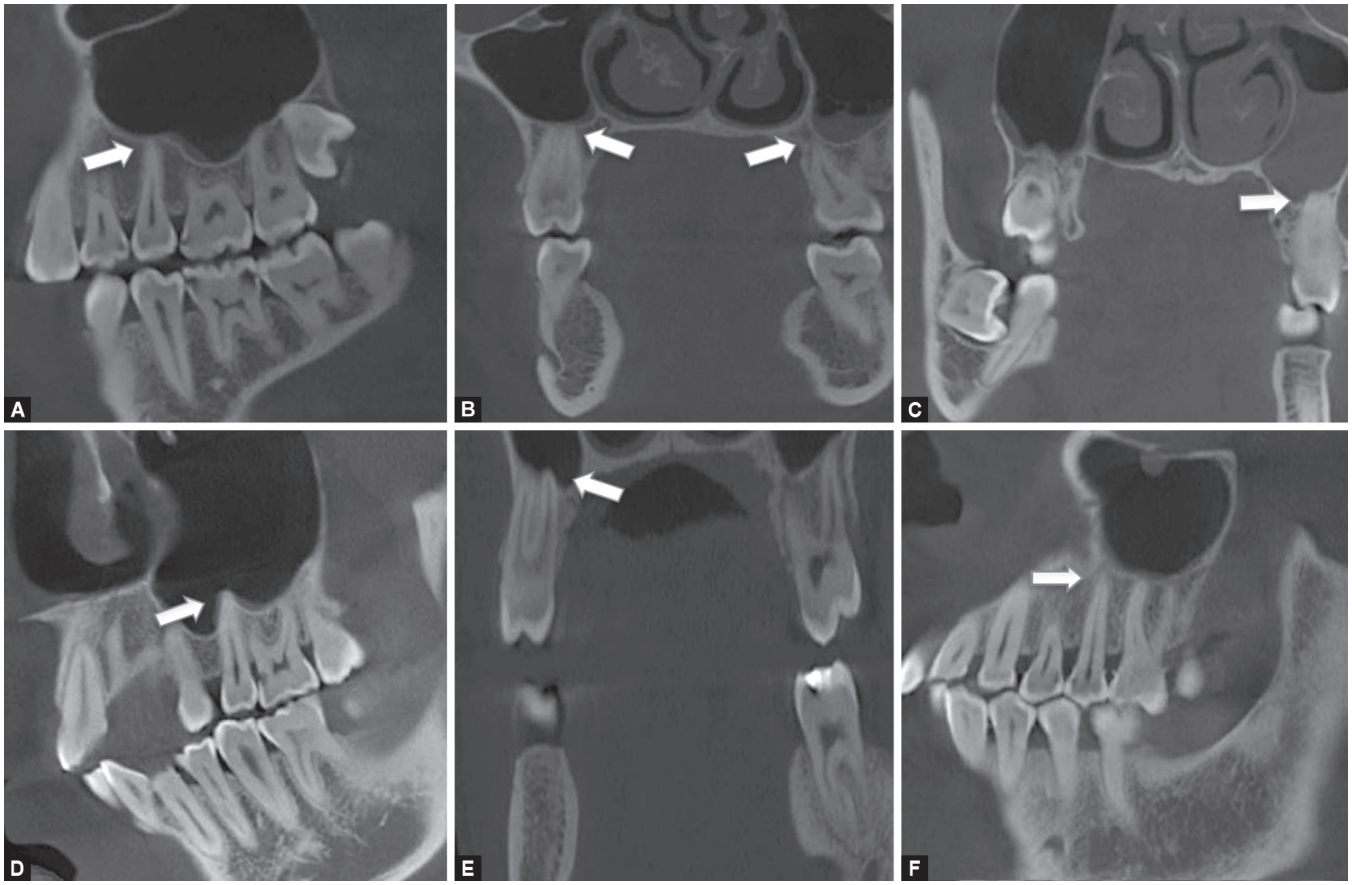
There are fewer odds to find right-sided palatal roots away from (OR = 0.003) ($p < 0.0001$) or in contact with the sinus (OR = 0.072)



Figs 1A to D: Axial view of CBCT images showing numbers of roots/canals of the maxillary second premolars (white arrows). (A) Both maxillary second premolars have only one root and one canal; (B) Left maxillary second premolar has one root and two canals; (C) Both maxillary second premolars have two roots and two canals; (D) Right maxillary second premolars with three roots and three canals

Table 1: Descriptive statistics of demographics and dental findings

			Teeth No. = 602	*Subtotal*	*Total (N)*
Gender; *n* (%)	Male		156 (51.83)		301 (# of subjects)
	Female		145 (48.17)		
Roots; *n* (%)	Right	One root	234 (77.74)	370	733 (Total # of Roots)
		Two roots	65 (21.59)		
		Three roots	2 (0.66)		
	Left	One root	240 (79.73)	363	
		Two roots	60 (19.93)		
		Three roots	1 (0.33)		
	Total	One root	474 (78.74)		
		Two roots	125 (20.76)		
		Three roots	3 (0.5)		
Canals; *n* (%)	Right	One canal	115 (38.21)	489	963 (Total # of canals)
		Two canals	184 (61.13)		
		Three canals	2 (0.66)		
	Left	One canal	128 (42.52)	474	
		Two canals	172 (57.14)		
		Three canals	1 (0.33)		
	Total	One root	243 (40.36)		
		Two roots	356 (59.14)		
		Three roots	3 (0.5)		
Age; Mean ± SD			29.59 ± 10.94		301



Figs 2A to F: CBCT images in different views showing the relationships between buccal and palatal roots of the maxillary second premolars and the maxillary sinus (white arrows). (A and B) Roots are in contact with the sinus; (C, D, and E) Roots are located inside the sinus; (F) Root located outside the sinus

Table 2: Prevalence of root proximity to sinus

		Single root			*Buccal root*			*Palatal root*		
		Outside sinus	*In contact*	*Inside sinus*	*Outside sinus*	*In contact*	*Inside sinus*	*Outside sinus*	*In contact*	*Inside sinus*
Right tooth *n* (%)	Single	174 (74.36)	40 (17.09)	20* (8.55)						
	Two roots				41 (63.08)	13 (20.0)	11 (16.92)	42 (64.62)	13 (20.0)	10 (15.38)
	Three roots				4 (100.0)			1 (50.0)		1 (50.0)
Left tooth *n* (%)	Single	171 (71.25)	46 (19.17)	23* (9.58)						
	Two roots				35 (58.33)	15 (25.0)	10 (16.67)	36 (60.0)	13 (21.67)	11 (18.33)
	Three roots				2 (100.0)			1 (100.0)		

*Fisher exact test is significant at $p < 0.0001$

Table 3: Sinus proximity of teeth with single rooted: Ordinal regression

		Right		*Left*	
Variable	*Category*	*OR*	*p-value*	*OR*	*p-value*
Age		0.916	<0.0001	0.953	0.007
Gender	Male	1.45	0.229	1.17	0.596
	Female	Reference		Reference	
Canal number	One	0.854	0.609	0.991	0.975
	Two	Reference		Reference	

Reference group: Inside the sinus

Table 4: Sinus proximity of teeth with multiple roots (Buccal root) ordinal regression

		Right		*Left*	
Variable	*Category*	*OR*	*p-value*	*OR*	*p-value*
Age		0.803	0.622	0.956	0.430
Gender	Male	0.827	0.805	5.51	0.152
	Female	Reference		Reference	
Palatal Root	Away	0.002	<0.0001	0.00002	<0.0001
	In contact	0.079	0.010	0.006	0.001
	Inside	Reference		Reference	
Canal number	Two	0.021	0.019		
	Three	Reference			

Reference group: Inside the sinus

Table 5: Sinus proximity of teeth with multiple roots (Palatal root) ordinal regression

		Right		*Left*	
Variable	*Category*	*OR*	*p-value*	*OR*	*p-value*
Age		0.953	0.286	0.803	0.622
Gender	Male	1.87	0.397	0.827	0.805
	Female	Reference		Reference	
Buccal Root	Away	0.003	<0.0001	0.002	<.0001
	In contact	0.072	0.010	0.079	0.010
	Inside	Reference		Reference	
Canal number	Two			0.021	0.019
	Three			Reference	

Reference group: inside the sinus

(p = 0.01). Similarly applies to the left-sided palatal roots: A way (OR = 0.002) (p < 0.0001), in contact (OR = 0.079) (p = 0.01). There are fewer odds of finding two canalled left-sided teeth to be away from the sinus (OR = 0.021) (p = 0.019) (Table 5).

Thus, the majority of maxillary second premolars were single-rooted (78.74%), two canals (59.1%), and roots were predominantly (69.17%) outside the maxillary sinus in the studied population. There was a significant correlation between the number of roots and the number of canals.

Discussion

The current study found variations in the root and canal number and morphology among the Saudi Arabian population in Jazan province. The majority of the observed teeth were single-rooted (78.74%), followed by two-rooted (20.76%). Three-rooted second premolars were exceedingly rare (Table 1). The visualization of three-rooted premolars may be onerous using a standard intraoral radiograph. This incidence is undoubtedly tied to race. When anticipated, perhaps in Indian (35%), Egyptian (26%), or Turkish (50.64%) populations, these rare cases can be more effectively managed.[19–21]

Multiple roots must be suspected when the mesiodistal width of the mid-root image is equal to or greater than the width of the crown.[32]

The findings of the present study are consistent with those of Elnour et al. who reported that single-rooted maxillary second premolar was the most common morphology (67%) in a Saudi Arabian population.[9] The findings of three-rooted maxillary second premolars are quite rare (0.5%) in the present study which broadly supports the work of other studies in this area likening the incidence rate of three-rooted premolars to approximately 2% in various populations.[8,33,34]

Although a majority of the maxillary second premolars examined had one root, the majority had two canals. A wide number of studies have reported on the morphological variations in the root canal systems of second premolars. Their incidence ranges from 34.4% to 44.2% to 54.4% based on the population examined.[10,34,35] The current study findings are aligned with earlier reports by Elnour et al. (65%)[9] and Elkady and Allouba (69%)[36] indicating a greater likelihood of finding a second canal in the maxillary second premolar in patients of Arab ethnicity. Clinically, the rate of locating two canals is relatively low. The failure to locate, debride and obturate the secondary canal could lead to endodontic treatment failure. Bearing in mind the radiation hazards, pre-existing relevant CBCT scans can provide additional information regarding the number of canals. The use of an operating microscope may also increase the detection rate of second canals.[37]

In the present study, around 69.17% of maxillary premolars roots were located outside the maxillary sinus, 19.1% were in contact with the sinus and 11.73% were inside the sinus (Fig. 2). This has implications for the maxillary sinus in the case of endodontic treatment of the second premolars. It is essential to consider the spatial relationship between the maxillary second premolars'

roots and the floor of the maxillary sinus during surgical and non-surgical root canal treatment planning. The close anatomic relationship of the sinus to the roots of the premolars renders this region susceptible to morbid situations due to dental causes or therapeutic intervention. According to the American Association of Endodontists, more than 40% of maxillary infections are odontogenic in their origin. The palatal and buccal roots of the second premolar are found close to or inside the sinus.[38,39] The proximity of these roots can be a risk to maxillary sinus perforation or sinusitis. The current study findings are similar to the results of Yan et al. who reported that the buccal root of the second premolar is close to the maxillary sinus floor.[40] Cone beam computed tomography scans may be indicated in patients for surgical planning when root projection into the sinus may be suspected after panoramic radiography.

The maxillary sinus undergoes change with age and habits. Age and gender were considered a factor in the distance between the root apices and the maxillary sinus with age seen as a significant predictor for single-rooted teeth to be proximal to the sinus.

The results of this study confirm the presence of variations in the second maxillary premolar canal morphology and the need for a careful radiographic examination of these teeth before non-surgical and surgical endodontic therapy. Clinically, identifying the prevalent anatomy of the root and canal in a population can reduce iatrogenic errors during endodontic treatment. The variance of the root canal anatomy and morphology in the maxillary second premolar predicts the level of difficulty of the cleaning and shaping process. Proper knowledge of the anatomical relationship between the maxillary teeth and the maxillary sinus can avoid complications that can result from surgical and non-surgical endodontic treatment.

Larger scale studies on different populations can serve to identify diverging trends in root canal anatomy and morphology, providing an evidence base for clinicians. Further studies should examine the axial plane view of the CBCT for the thickness of the dentin wall at critical points along the canal. This can serve to espouse a conservative shaping approach that may be especially important when multiple canals may lead to thinner walls. Future research should be directed at customized approaches rather than a one-size-fits-all protocol for the instrumentation of teeth with morphological variations. Complex variations among different ethnic groups necessitate the advancement of personalized endodontics that carefully assesses and adapts to the canal configuration and thickness of each tooth. A clinician must be cognizant of common root canal anatomical features and possible variations in different populations to prevent iatrogenic errors and ensure endodontic treatment success. These findings will be valuable evidence bases for dental clinicians who treat Saudi Arabian patients in the USA, UK, Australia, Europe, and other countries.

Conclusions

Maxillary premolars in a Saudi Arabian population showed a wide range of root canal anatomical variations. The current study identified rare morphologies such as three-rooted maxillary second premolars. Most maxillary second premolars were single-rooted with two canals. The majority of maxillary second premolars had one canal entrance per root. Most of the buccal and palatal roots of maxillary second premolars were outside the sinus.

References

1. Estrela C, Holland R, Estrela CR de A, et al. Characterization of successful root canal treatment. Braz Dent J 2014;25(1):3–11. DOI: 10.1590/0103-6440201302356.
2. Ahmed HMA, Hashem AA. Accessory roots and root canals in human anterior teeth: A review and clinical considerations. Int Endod J 2016;49(8):724–736. DOI: 10.1111/iej.12508.
3. Cantatore G, Berutti E, Castellucci A. Missed anatomy: Frequency and clinical impact. Endod Top 2006;15(1):3–31. DOI: https://doi.org/10.1111/j.1601-1546.2009.00240.x.
4. Hoen MM, Pink FE. Contemporary endodontic retreatments: An analysis based on clinical treatment findings. J Endod 2002;28(12):834–836. DOI: 10.1097/00004770-200212000-00010.
5. Song M, Kim HC, Lee W, et al. Analysis of the cause of failure in nonsurgical endodontic treatment by microscopic inspection during endodontic microsurgery. J Endod 2011;37(11):1516–1519. DOI: 10.1016/j.joen.2011.06.032.
6. Scavo R, Martinez Lalis R, Zmener O, et al. Frequency and distribution of teeth requiring endodontic therapy in an Argentine population attending a specialty clinic in endodontics. Int Dent J 2011;61(5):257–260. DOI: 10.1111/j.1875-595X.2011.00069.x.
7. Vertucci F, Seelig A, Gillis R. Root canal morphology of the human maxillary second premolar. Oral Surg Oral Med Oral Pathol 1974;38(3):456–464. DOI: 10.1016/0030-4220(74)90374-0.
8. Pécora JD, Sousa Neto MD, Saquy PC, et al. *In vitro* study of root canal anatomy of maxillary second premolars. Braz Dent J 1993;3(2):81–85. PMID: 8241762.
9. Elnour M, Khabeer A, AlShwaimi E. Evaluation of root canal morphology of maxillary second premolars in a Saudi Arabian sub-population: An *in vitro* microcomputed tomography study. Saudi Dent J 2016;28(4):162–168. DOI: 10.1016/j.sdentj.2016.08.001.
10. Al-Ghananeem MMF, Haddadin K, Al-Khreisat AS, et al. The number of roots and canals in the maxillary second premolars in a group of jordanian population. Int J Dent 2014;2014:797692. DOI: 10.1155/2014/797692.
11. Peiris R, Arambawatta K, Pitakotuwage N. Root and canal morphology of maxillary premolars and their relationship with the crown morphology. J Oral Biosci 2022;64(1):148–154. DOI: 10.1016/j.job.2021.12.004.
12. Velmurugan N, Parameswaran A, Kandaswamy D, et al. Maxillary second premolar with three roots and three separate root canals. Aust Endod J 2005;31(2):73–75. DOI: 10.1111/j.1747-4477.2005.tb00230.x.
13. Soares JA, Leonardo RT. Root canal treatment of three-rooted maxillary first and second premolars – A case report. Int Endod J 2003;36(10):705–710. DOI: 10.1046/j.1365-2591.2003.00711.x.
14. Zeichner-David M, Oishi K, Su Z, et al. Role of Hertwig's epithelial root sheath cells in tooth root development. Dev Dyn 2003;228(4):651–663. DOI: 10.1002/dvdy.10404.
15. Versiani MA, Ordinola-Zapata R, Keleş A, et al. Middle mesial canals in mandibular first molars: A micro-CT study in different populations. Arch Oral Biol 2016;61:130–137. DOI: 10.1016/j.archoralbio.2015.10.020.
16. Sperber GH, Moreau JL. Study of the number of roots and canals in Senegalese first permanent mandibular molars. Int Endod J 1998;31(2):117–122. DOI: 10.1046/j.1365-2591.1998.00126.x.
17. Boruah LC, Bhuyan AC. Morphologic characteristics of root canal of mandibular incisors in North-East Indian population: An *in vitro* study. J Conserv Dent 2011;14(4):346–350. DOI: 10.4103/0972-0707.87195.
18. Reichart PA, Metah D. Three-rooted permanent mandibular first molars in the Thai. Community Dent Oral Epidemiol 1981;9(4):191–192. DOI: 10.1111/j.1600-0528.1981.tb01053.x.
19. Raj UJ, Mylswamy S. Root canal morphology of maxillary second premolars in an Indian population. J Conserv Dent 2010;13(3):148–151. DOI: 10.4103/0972-0707.71648.
20. Saber SEDM, Ahmed MHM, Obeid M, et al. Root and canal morphology of maxillary premolar teeth in an Egyptian subpopulation using two classification systems: A cone beam computed tomography study. Int Endod J 2019;52(3):267–278. DOI: 10.1111/iej.13016.

21. Kartal N, Özçelik B, Cimilli H. Root canal morphology of maxillary premolars. J Endod 1998;24(6):417–419. DOI: 10.1016/S0099-2399(98)80024-1.
22. Abella F, Teixidó LM, Patel S, et al. Cone-beam computed tomography analysis of the root canal morphology of maxillary first and second premolars in a spanish population. J Endod 2015;41(8):1241–1247. DOI: 10.1016/j.joen.2015.03.026.
23. Monsarrat P, Arcaute B, Peters OA, et al. Interrelationships in the variability of root canal anatomy among the permanent teeth: A full-mouth approach by cone-beam CT. PLoS One 2016;11(10):e0165329. DOI: 10.1371/journal.pone.0165329.
24. Obayashi N, Ariji Y, Goto M, et al. Spread of odontogenic infection originating in the maxillary teeth: Computerized tomographic assessment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2004;98(2):223–231. DOI: 10.1016/j.tripleo.2004.05.014.
25. Roque-Torres GD, Ramirez-Sotelo LR, Vaz SL de A, et al. Association between maxillary sinus pathologies and healthy teeth. Braz J Otorhinolaryngol 2016;82(1):33–38. DOI: 10.1016/j.bjorl.2015.11.004.
26. Melén I, Lindahl L, Andréasson L, et al. Chronic maxillary sinusitis. Definition, diagnosis and relation to dental infections and nasal polyposis. Acta Otolaryngol 1986;101(3–4):320–327. DOI: 10.3109/00016488609132845.
27. Bomeli SR, Branstetter BF IV, Ferguson BJ. Frequency of a dental source for acute maxillary sinusitis. Laryngoscope 2009;119(3): 580–584. DOI: 10.1002/lary.20095.
28. Blašković-Šubat V, Smojver I, Maričić B, et al. A computerized method for the evaluation of root canal morphology. Int Endod J 1995;28(6):290–296. DOI: 10.1111/j.1365-2591.1995.tb00318.x.
29. Omer OE, Al Shalabi RM, Jennings M, et al. A comparison between clearing and radiographic techniques in the study of the root-canal anatomy of maxillary first and second molars. Int Endod J 2004;37(5):291–296. DOI: 10.1111/j.0143-2885.2004.00731.x.
30. Neelakantan P, Subbarao C, Subbarao CV. Comparative evaluation of modified canal staining and clearing technique, cone-beam computed tomography, peripheral quantitative computed tomography, spiral computed tomography, and plain and contrast medium-enhanced digital radiography in studying root c. J Endod 2010;36(9):1547–1551. DOI: 10.1016/j.joen.2010.05.008.
31. Grande NM, Plotino G, Gambarini G, et al. Present and future in the use of micro-CT scanner 3D analysis for the study of dental and root canal morphology. Ann Ist Super Sanita 2012;48(1):26–34. DOI: 10.4415/ANN_12_01_05.
32. Sieraski SM, Taylor GN, Kohn RA. Identification and endodontic management of three-canalled maxillary premolars. J Endod 1989;15(1):29–32. DOI: 10.1016/S0099-2399(89)80095-0.
33. Weng XL, Yu SB, Zhao SL, et al. Root canal morphology of permanent maxillary teeth in the Han nationality in Chinese Guanzhong area: A new modified root canal staining technique. J Endod 2009;35(5): 651–656. DOI: 10.1016/j.joen.2009.02.010.
34. Jayasimha Raj U, Mylswamy S. Root canal morphology of maxillary second premolars in an Indian population. J Conserv Dent 2010;13(3):148–151. DOI: 10.4103/0972-0707.71648.
35. Yang L, Chen X, Tian C, et al. Use of cone-beam computed tomography to evaluate root canal morphology and locate root canal orifices of maxillary second premolars in a Chinese subpopulation. J Endod 2014;40(5):630–634. DOI: 10.1016/j.joen.2014.01.007.
36. ELKady AM, Allouba K. Cone beam computed tomographic analysis of root and canal morphology of maxillary premolars in Saudi subpopulation. Dent J 2013;59:3419–29.
37. Rashed B, Iino Y, Komatsu K, et al. Evaluation of root canal anatomy of maxillary premolars using swept-source optical coherence tomography in comparison with dental operating microscope and cone beam computed tomography. Photomed Laser Surg 2018;36(9):487–492. DOI: 10.1089/pho.2017.4416.
38. Eberhardt JA, Torabinejad M, Christiansen EL. A computed tomographic study of the distances between the maxillary sinus floor and the apices of the maxillary posterior teeth. Oral Surg Oral Med Oral Pathol 1992;73(3):345–346. DOI: 10.1016/0030-4220(92)90133-b.
39. Kang SH, Kim BS, Kim Y. Proximity of posterior teeth to the maxillary sinus and buccal bone thickness: A biometric assessment using cone-beam computed tomography. J Endod 2015;41(11):1839–1846. DOI: 10.1016/j.joen.2015.08.011.
40. Yan Y, Li J, Zhu H, et al. CBCT evaluation of root canal morphology and anatomical relationship of root of maxillary second premolar to maxillary sinus in a western Chinese population. BMC Oral Health 2021;21(1):358. DOI: https://doi.org/10.1186/s12903-021-01714-w.