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CBCT based correlation of the root canal anatomy of upper second bicuspid and its proximity to maxillary sinus floor in a sample of Egyptian population. Retrospective study

Wessam M. Youssef [*1], ***Ahmed M. Hossam El-Din*** [*2], ***Heba Ahmed Seif Allah ElAsfouri*** [*3], ***Eyad A. Elbattawy*** [*4]

[1] *Researcher *- Surgery and Oral medicine department, Oral and Dental research institute, National Research Center, Egypt*
[2] *Associate Professor – Oral & Maxillofacial radiology Department, Faculty of Dentistry-MSA University, Egypt*
[3] *Associate Professor-Endodontic department. Faculty of dentistry. Cairo University*
[4] *Researcher-Restorative and Dental materials department, Oral and Dental research institute, National Research Center, Egypt*

Abstract

To assess the root canal morphology, anatomy, and anatomical relationship between the roots of maxillary second premolars and maxillary sinus in the Egyptian population using Cone Beam Computed Tomography (CBCT). A dentist has to be knowledgeable about the different routes that a root canal takes to reach the apex. In this sense, CBCT is beneficial since it delivers three-dimensional imaging, which makes it possible to observe a single tooth in any plane. A total of 300 patients had their CBCT scans. The number of roots and canals, the architecture of the canal system categorized by the Vertucci standard, and the distance from the root tip to the maxillary sinus floor were all appropriately evaluated based on measurements of the teeth taken on the axial, coronal, and sagittal sections. Statistical analysis was performed with SPSS 16 ® (Statistical Package for Scientific Studies), All data and comparisons were performed by Chi square test. Different canal categories demonstrated that Type I 197 (61.4%) was significantly the highest, while Type IV 12 (3.8%) was significantly the lowest, while no case revealed Type VI, Type VII, and Type VIII 0 (0%). Distances between the roots and the maxillary sinus floor were presented as Type I 169 (51.5%) was significantly the highest, while Type IV 12 (3.69%) was significantly the lowest. There were numerous morphological differences in the roots and canals of the maxillary second premolars and was a greater proportion of type 1 sinus relation of the roots of these premolars to the maxillary sinus floor (MSF) in the Egyptian population.

Keywords: Cone Beam Computed Tomography, Maxillary sinus floor, Root canal morphology

Full length article **Corresponding Author, Wessam M. Youssef,* e-mail: wessam2004@gmail.com

1. Introduction

As opposed to the front teeth, which greatly contribute to our smile, or the first molars, which form the occlusal basis, maxillary second premolars appear to be inconsequential in the dental arch. Nonetheless, a multitude of investigations has documented a remarkably distinct and intricate root and canal architecture for the upper second premolar teeth, exhibiting extra canals and roots. This may differ based on racial and regional background. Studies revealed that granuloma and dens evaginatus are two possible illnesses affecting the maxillary second premolars.

Some even asserted that one of the maxillary teeth that receive endodontic treatment the most frequently is the second premolar. In addition, premolars are frequently chosen for extraction cases in orthodontic treatment, which presents challenges for the clinicians because the root may be near or even encircled by the floor of the maxillary sinus. When the inflammation of the tooth pulp was caused by any of the pathogenic reasons listed above, regular root canal therapy would be the primary course of action [1]. One of the hardest teeth to treat endodontically is the maxillary second premolar. Numerous factors, including the number of roots and canals, the orientation and longitudinal depressions of the roots, the different pulp cavity topologies, and the challenges associated with radiological visualization of the apical limit, could be the cause of this [2]. Maxillary second premolars typically have an oval-shaped canal with a single root. Second premolars with two roots and independent root canals are less common [3]. However, it is possible to find two canals in a single root. Between 4 and 50 percent of teeth in the apical area have two canals [4-6]. Numerous investigations document a significant degree of variation in the maxillary second premolars, with infrequent observations of third canals [7-8]. Although the precise cause of the creation of numerous canals is unknown, damage to the epithelial root sheath of Hertwig during development and genetics are considered the likely culprits [9]. The factors that cause variance in root canal shape are genetics and ethnicity [10-13]. Understanding the current variances in root canal therapy can be enhanced by looking at a particular ethnic group. It is rare and varies among different ethnic groups for maxillary second premolars to have a two-rooted structure. Research has revealed that there are variations in root canal geometry and a range of frequencies of double-rooted maxillary second premolars. This information can help with endodontic treatment of second premolars, which present a special difficulty for endodontists due to population diversity [14]. It has also been noted that the occurrence of three canals in maxillary premolars ranges from 0 to 10% [15]. Consequently, it is rather crucial for therapy to evaluate root morphology and root canal morphology prior to treatment [16]. One recognized technique for examining and visualizing the unclear morphology of a single tooth is cone-beam computed tomography (CBCT). The root anatomy is displayed using traditional radiography techniques as a two-dimensional plenary projection. Instead of only being able to view a single tooth in the predetermined "default views" of periapical radiographs [17] CBCT offers three-dimensional imaging in the axial, sagittal, and coronal dimensions. This allows for imaging of root canal systems with lower radiation doses, higher resolution, and no superimposition [18]. The largest bilateral air sinus in the maxilla body, structured like a pyramid, is called the maxillary sinus (MS). It differs in size, form, and location in distinct people as well as in different parts of the same person. Gender and ethnic group differences may also exist in the dimensions of the MS [19]. The relationship between the size and degree of pneumatization of the MS, as well as the maxillary posterior teeth, may help to explain the morphological heterogeneity. About half of the population has an inferior wall of the MS that is curved and extends across neighboring teeth or roots, resulting in elevations in the antral surface or protrusions of the root apices into the sinus cavity [20-21]. When diagnosing and arranging therapy for the posterior region, the relationship between the MS and the root apices of the teeth is clinically significant. It has been stated that ~10–12% of all cases of sinusitis are caused by orthodontia, which results in maxillary sinusitis [22]. It is brought on by an oral cavity or nasal ostium microbial infection [23]. When dental materials are extruded into the sinus from the apex of the neighboring teeth, tooth infections, extractions, foreign bodies, or other causes can cause sinusitis that starts in the oral cavity. Furthermore, the near proximity of the tooth apex and the posterior teeth's necrotic pulp to the maxillary sinus enhances the risk of developing sinusitis [24]. The disease of these teeth may impact the maxillary sinus's Schneiderian membrane's mucosal thickness and sinusitis is indicated by mucosal thickness greater than 2 mm [25-27]. The root canal preparation tools, infected debris, root canal irrigation solutions, intracanal medications, sealers, and root canal filling materials may extrude to the sinus if the sinus floor is perforated at any point throughout the root canal treatment process. Furthermore, for a practitioner who has a solid understanding of the architecture of the sinuses, the risk of maxillary sinus perforation during endodontic surgery is minimal. The majority of earlier research evaluating the connection between MS and upper teeth has used two-dimensional (2D) imaging. Nevertheless, because 2D imaging compresses 3D structures, it provides insufficient information and increases the possibility of misinterpreting the relationship between upper teeth and MS and misdiagnosing pathology related to the posterior maxilla [28-34]. Cone-beam computed tomography (CBCT) as a three-dimensional imaging could provide a way to see the intricate relationship between MS and upper (pre)molars more clearly. Additionally, CBCT provides a precise diagnostic method for evaluating sinusitis with a potential dental origin. Additionally, with the advent of the state-of-the-art software programs for image analysis, a precise anatomical relationship based on CBCT volumetric data can be further quantified [35-36]. Considering the distinct anatomical features in different populations, and variations within an individual between different maxillary premolars, this research aimed to evaluate the root anatomy, root canal morphology and the anatomical relationship between the roots of maxillary second premolars and maxillary sinus floor using CBCT examination.

2. Materials and Methods

Ethical research and Review Board of a Dental College with a reference REC-D 848-3 approved the study. Data were collected from archived CBCT images taken from 2021-2023 at the radiology department of the college. CBCT images of 300 maxillary second premolars were acquired from 300 patients (aged 21-65 y/o) for this cross-sectional retrospective study. The CBCT images used in this study were taken for other purposes like implant planning, prosthesis, surgery, orthodontic and endodontic purposes. Whole data have been screened according to criteria below to avoid misleading by image artifacts, manmade changes or teeth moving.

Inclusion criteria for CBCT image analysis were as follows

1. No dental trauma or dysplasia (fusion, central cusp deformity, dens invaginatus, etc.)
2. No periapical lesions or orthodontic treatment.
3. No previous root canal treatment or post- or crown restoration.
4. Mature root apical foramen without root resorption or calcification.
5. No missing adjacent or opposite jaw tooth.
6. No maxillary deformity, trauma or maxillofacial tumor.

Exclusion criteria were as follows

Teeth with dental trauma or dysplasia, teeth with periapical lesions or orthodontic treatment, previous root canal treatment, immature root apical foramen with root resorption or calcification, missing adjacent or opposite jaw tooth, maxillary deformity or trauma etc.

2.1. Sample size calculation

According to the results of a previous study, in which the prevalence was (93%)- by adopting a confidence interval of (95%), a margin of error of (5%) with finite population correction; The predicted sample size (n) was a total of (100) cases. Sample size was calculated by using EPI INFO version 7.2.5.0 [37]. The projected sample size was raised to (300) cases, males revealed 158 (52.7%) with age (42.39 ± 12.59) while female revealed 142 (47.3%) with age (41.63 ± 12.49), in order to boost the study power and decrease the level of uncertainty.

2.2. Radiographic Technique

The study was carried out in maxillofacial radiology clinics, using existing data from departmental CBCT archives. The CBCT images were taken with a NewTom GIANO HR 3D machine FOV (4x6) with standardized tube current and voltage of 12.5 mA and 90 kVp. Those images were shoot by an experienced radiologist following the manufacturer's instructions with lowest dose radiation. The NNT 3D imaging software then reconstructed all CBCT scans.

2.3. Image Analysis

Two Endodontists evaluated all the images. Two oral radiologist's opinions were considered as the final golden standard in case of inevitable disagreement on any image. Views of maxillary second premolars from pulp chamber to apical foramen on the coronal, sagittal and axial sections were observed to analyze the root canal morphology. Data of teeth were measured and recorded as follows:

- The root numbers
- The number and configuration of canal (based on Vertucci classification [35].
- The distance from each root to the maxillary sinus floor

In this research 300 samples (158 males and 142 females) were evaluated, with second premolars root apices relation to the floor of maxillary sinus, using cross-sectional images, and classified them into four types of vertical relationships according to Shahbazian etal. [33].

Type I (>0.5mm)
Type II (≤0.5mm)
Type III(=0mm)
Type IV (<0mm)

2.4. Statistical analysis

Statistical analysis was performed with SPSS 16 ® (Statistical Package for Scientific Studies), Graph pad prism & windows excel and presented in 3 tables and 3 graphs. All data were as frequency (N) and percentages (%) except age was presented as mean (M) and standard deviation (SD), all comparisons were performed by using Chi square test.

3. Results and discussion

In this study, male revealed 158 (52.7%) with age (42.39 ± 12.59) while female revealed 142 (47.3%) with age (41.63 ± 12.49), as presented in table (1) and figure (4).

3.1. Different canal categories (according to Vertucci's classification)

Different canal categories (according to Vertucci's classification) were presented in table (2) and figure (5) and demonstrated that Type I (figure1A) 197 (61.4%) was significantly the highest, while Type IV (figure1D) 12 (3.8%) was significantly the lowest, while no case revealed Type VI, Type VII, and Type VIII 0 (0%). Distribution of different canal categories among gender revealed insignificant difference between male and female as P=0.65. On the other hand, distribution of different canal categories among number of roots demonstrated significant difference as P<0.0001, as in 1 root Type I demonstrated only in 149 (54.8%), while in 2 roots demonstrated in 28 (100%).

3.2. Distance from root tip to the maxillary sinus floor

Different distances between the roots and the maxillary sinus floor were presented in table (3) and figure (7). There was a significant difference between different distances as P<0.0001, as Type I 169 (51.5%) was significantly the highest, while Type IV 12 (3.69%) was significantly the lowest. Distribution of different distances among number of roots revealed a significant difference between different distances in 1 and 2 roots as P<0.0001. In teeth with 1root, Type I was significantly the highest (figure 2A) 132 (48.5%), while Type IV (figure 2D) was significantly the lowest 12 (4.4%). In 2 roots, regarding buccal root all cases demonstrated Type I 28 (100%), but in palatal root Type III(figure 2C) was significantly the highest 16 (57.1%) while Type II (figure 2B) 3 (10.7%) was Significantly the lowest.

A good endodontic treatment requires meticulous clinical and radiographic exams. Given that CBCT can analyses and assess root canal morphology in three dimensions, it is purported to be a superior method than intraoral periapical radiography for reliably detecting root canal anatomy [38]. Premolars are known to be treated with root canals on a regular basis; research reports that these teeth show a variety of variances. Numerous investigations have demonstrated that ethnicity also has a discernible impact on the anatomy and morphology of these teeth. With the use of CBCT, the current study attempted to examine the root anatomy, root canal morphology, and the anatomical link between the roots and maxillary sinus of maxillary second premolars [39]. A variety of in-vitro techniques, like as micro-computed tomography and the tooth-clearing method with or without a microscope, have been recommended for examining the morphology of the root canal [40-46]. Unfortunately, the sample size is limited because all in vitro methods are only suitable for dental extractions. When compared to micro computed tomography, CBCT is thought

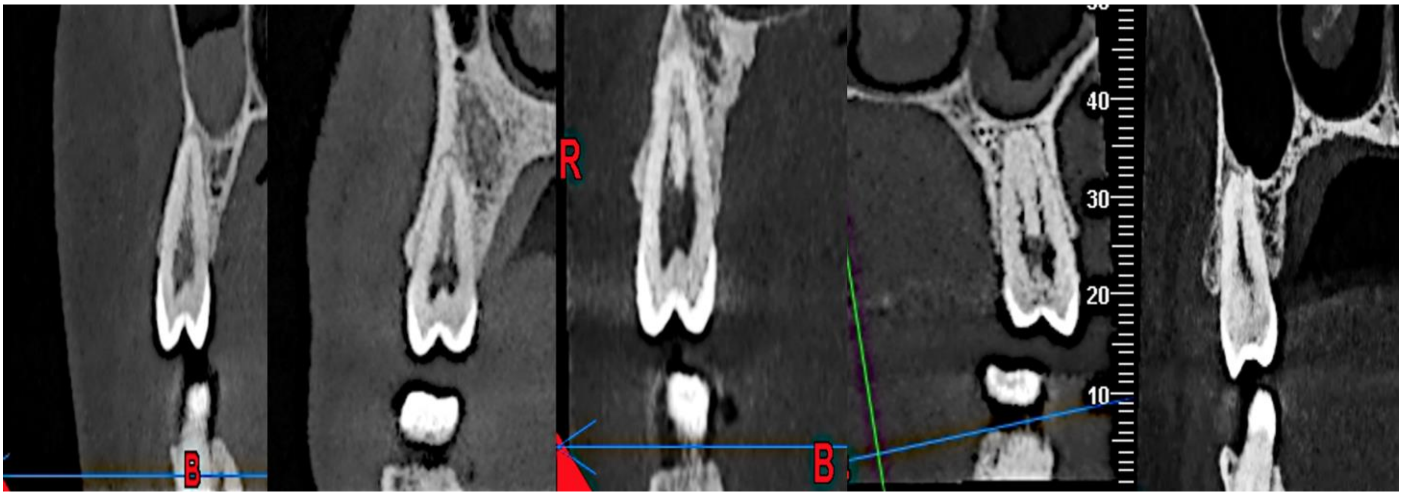

Figure 1(A) **Figure 1(B)** **Figure 1(C)** **Figure 1(D)** **Figure 1(E)**

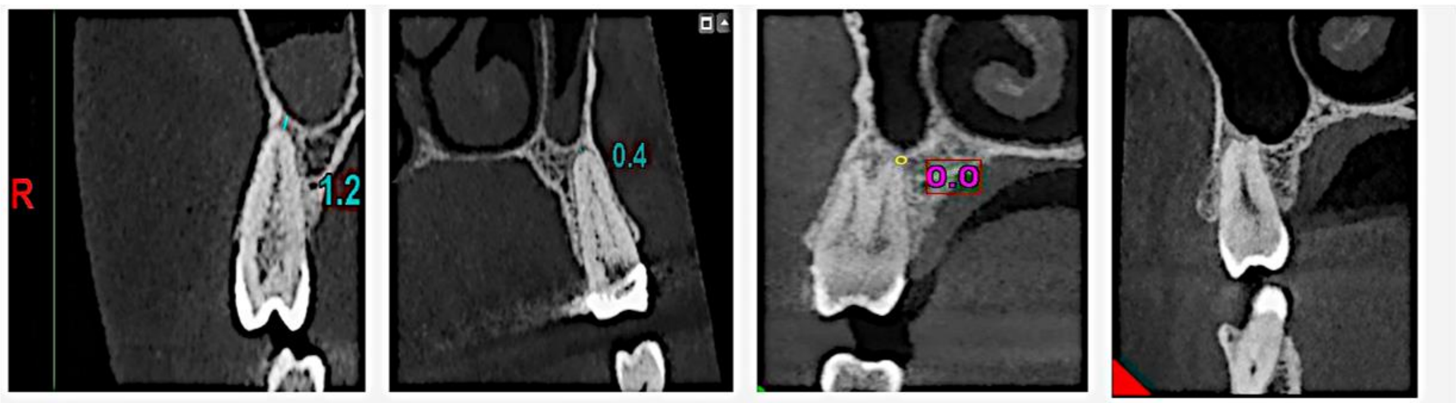

Figure 2(A) **Figure 2(B)** **Figure 2(C)** **Figure 2(D)**

Table 1. Demographic data of 300 cases

Gender N(%)	**Male**	158 (52.7%)
	Female	142 (47.3%)
Age M(SD)	**Male**	42.39 (12.89)
	Female	41.62 (12.49)
	Overall	42.02 (12.69)

N: frequency %: percentages
M:mean SD: standard Deviation

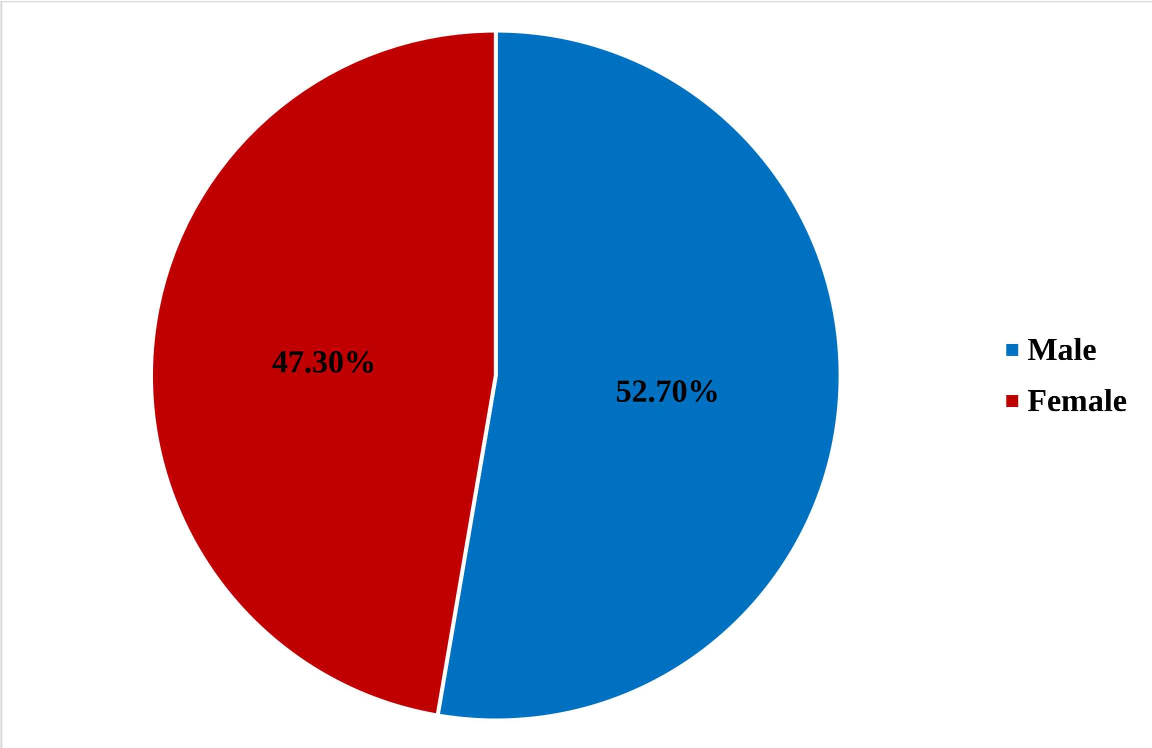

Figure 3. Pie chart showing Gender distribution

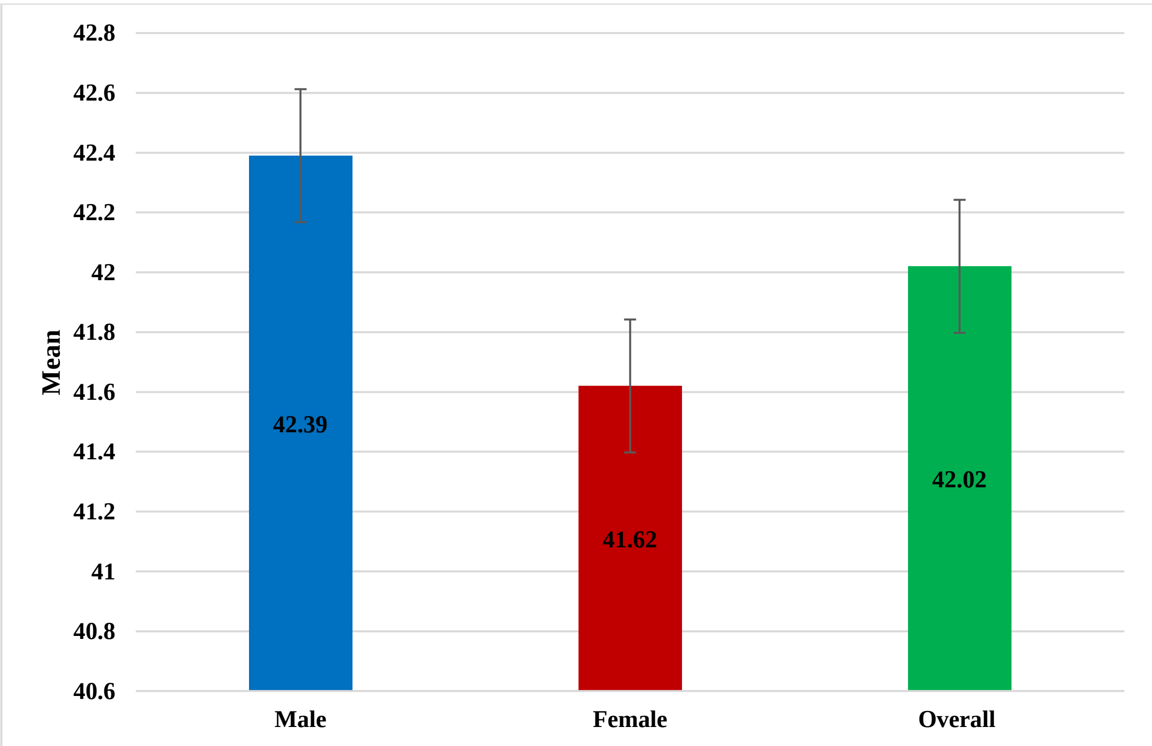

Figure 4. Bar chart showing age among studied cases.

Table 2. Different canal category (according to Vertucci's classification) and distribution among gender and among number of roots

Different canal categories		Total		Type I		Type II		Type III		Type IV		Type V		Type VI		Type VII		Type VIII		P value
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	
Total		320	100	197	61.4	59	18.5	31	9.7	12	3.8	21	6.6	0	0.0	0	0	0	0	<0.0001*
Gender	Male	158	52.7	97	61.4	30	19.0	16	10.1	6	3.8	9	5.7	0	0.0	0	0	0	0	0.65
	Female	142	47.3	80	56.3	29	20.4	15	10.6	6	4.2	12	8.5	0	0.0	0	0	0	0	
No. of roots	1 root	272	90.6	149	54.8	59	21.7	31	11.4	12	4.4	21	7.7	0	0.0	0	0	0	0	<0.0001*
	2 roots	28	9.4	28	100	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0	0	0	

N: frequency %: percentages *Significant difference as $P<0.05$

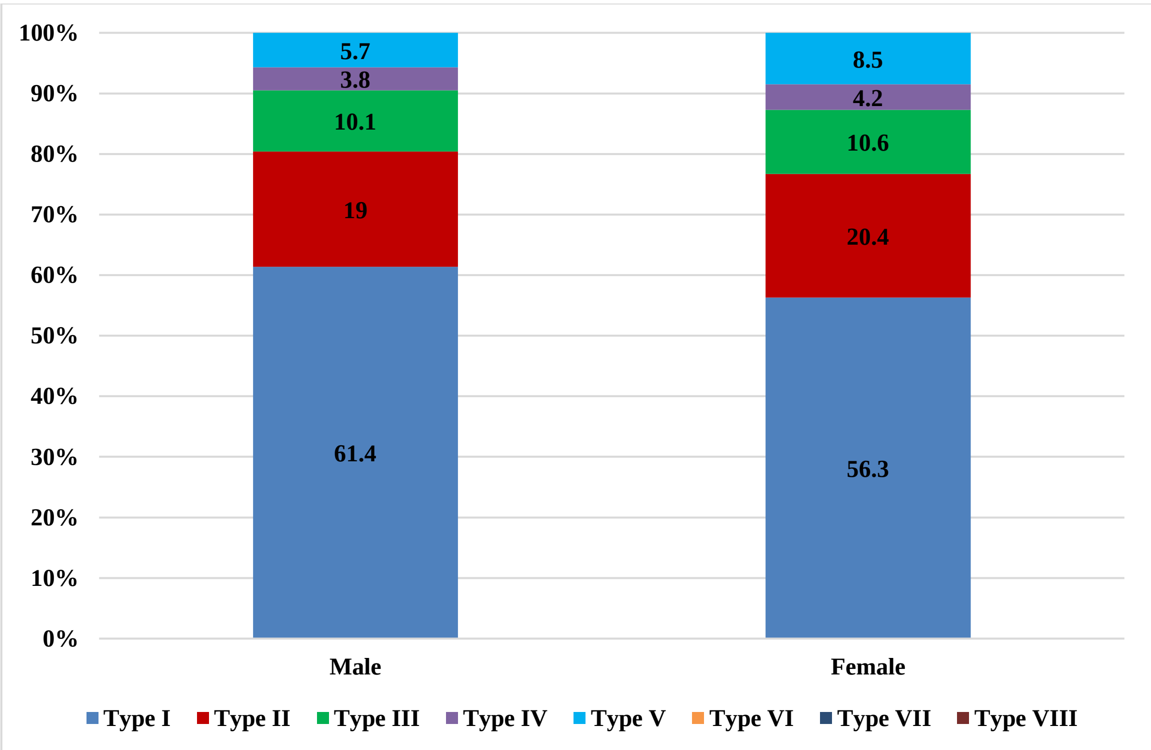

Figure 5. Bar chart showing different canal category (according to Vertucci's classification) and distribution among gender.

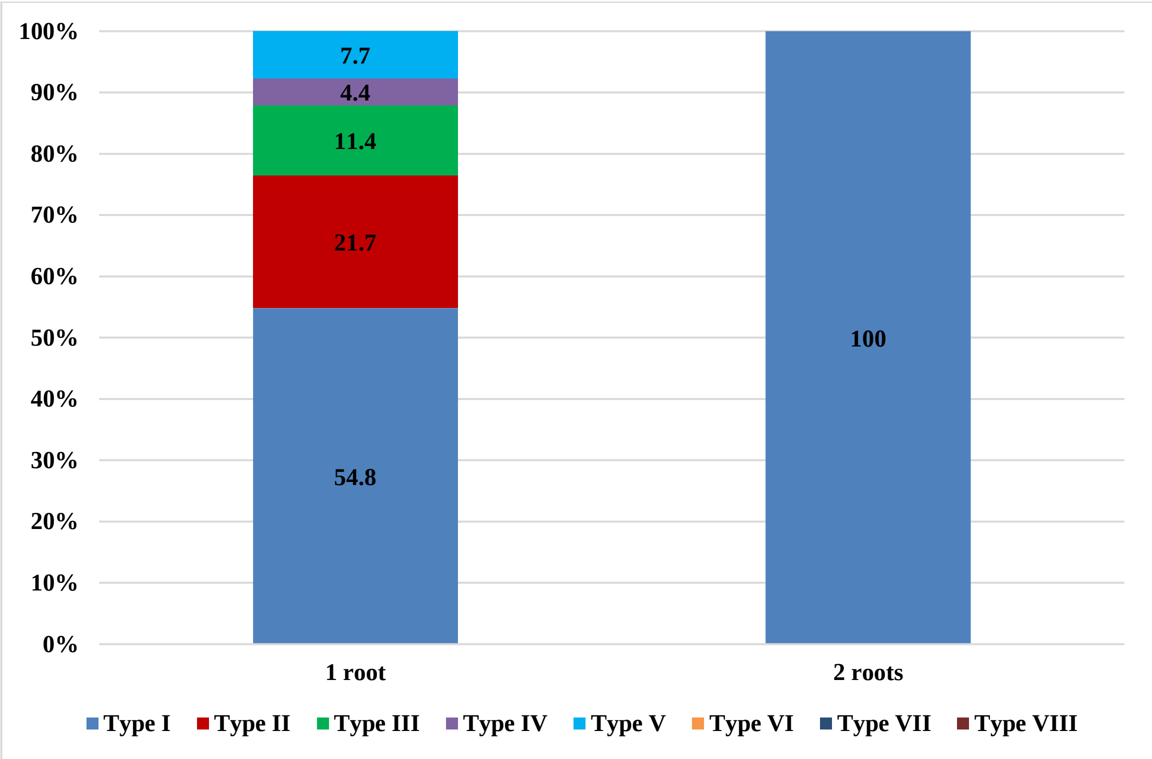

Figure 6. Bar chart showing Different canal category (according to Vertucci's classification) and distribution among number of roots.

Table 3. Distance form root to the maxillary sinus floor (according to the method of Shahabazian et al) and distribution among number of roots

Proximity to sinus													
			Total		**Type I**		**Type II**		**Type III**		**Type IV**		**P value**
			N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	
Total			300	0	169	51.5	102	31.09	45	13.71	12	3.69	**<0.0001***
No. of roots	**1 root**		272	90.6	132	48.5	99	36.4	29	10.7	12	4.4%	**<0.0001***
	2 roots	**Buccal**	28	9.3	28	100	0	0.0	0	0.0	0	0.0%	
		Palatal	28	9.3	9	32.1	3	10.7	16	57.1	0	0.0%	

N: frequency %: percentages *Significant difference as P<0.05.

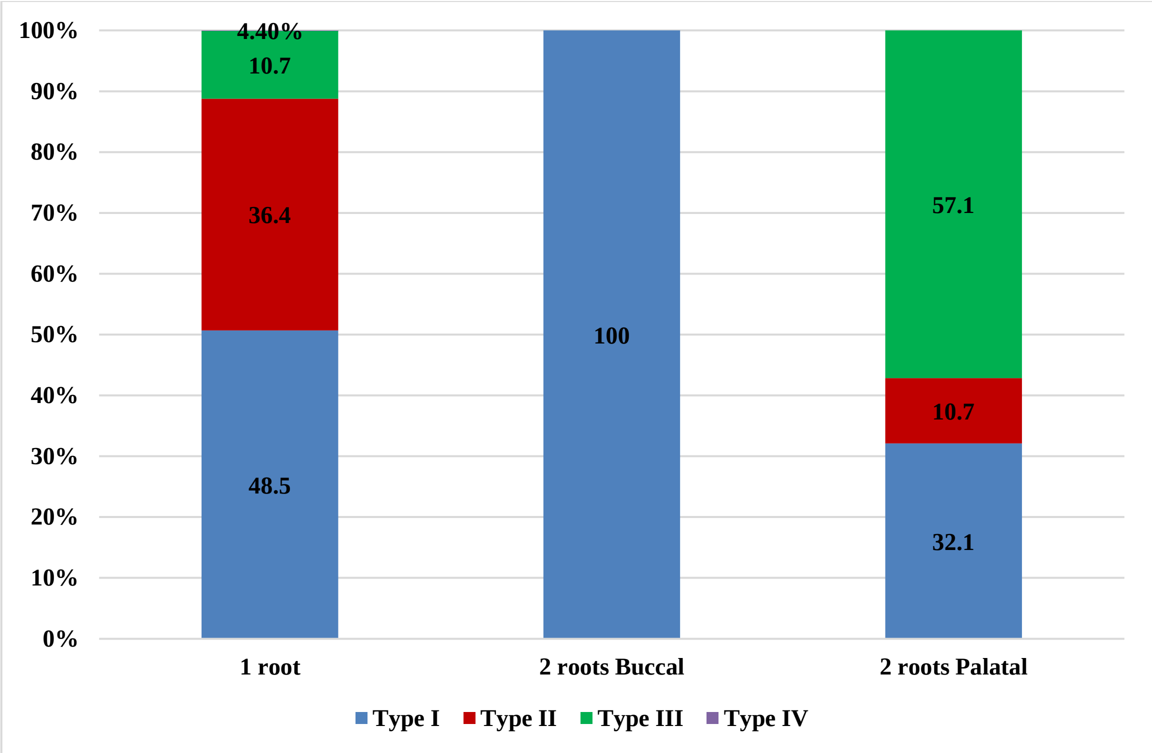

Figure 7. Bar chart showing Distance form root to the maxillary sinus floor and distribution among number of roots

to be a reliable, non-destructive technique for evaluating the morphology of root canals. It offers high quality pictures at a definite reduction in radiation dosage and expense [47]. Factors such as age, gender, and ethnicity were taken into account [48-50]. In order to achieve this, we looked at a large enough sample of CBCT imaging data to reduce sampling bias. Vertucci classification was used to categories the sample canal configurations, because it is the most widely used approach [35]. Except for types VI, VII, and VIII, all classes of Vertucci canal morphology were discovered in the current investigation. The vast majority of maxillary second premolars in this study had only one root, according to observations (90.6%). Since other earlier studies found far lower rates, such as in the Jordanian population (55.3%) [51] and the South African subpopulation (78.2%), this incidence appears to have changed with race [52], Spanish people (82.9%) [53], people in Saudi Arabia (85.2%) [54] the population of Iranians (91%) [55] and Turkish Cypriots (91.9%) [56]. It's important to note that earlier studies by Li (96.2%) [57] and Hu (95.2%) [58] in the Chinese subpopulation, had comparable outcomes. Different canal categories (according to Vertucci's classification) were presented in this study and demonstrated that Type I 197 (61.4%) was significantly the highest, while Type IV 12 (3.8%) was significantly the lowest, while no case revealed Type VI, Type VII, and Type VIII 0 (0%). Types I and II, however, were dominating. This demonstrates that regardless of the root shape, more than half of cases of maxillary second premolars have two canals. This was consistent with the majority of earlier research

[53,58,59,60,61].

Distribution of different canal categories among gender revealed insignificant difference between male and female as P=0.65. Gender has little effect on the overall shape of roots, which is consistent with other research [62-63]. These results disagreed with those of another study [53] which found a statistically significant difference in the number of roots and root canals between male and female patients. Understanding the anatomical connection between maxillary sinus (MS) and posterior maxillary teeth (PMT) is essential when evaluating MS problems related to the inflammatory response that may have a dental origin [26,64]. Previous research has determined that two-dimensional imaging modalities, including panoramic and intraoral x-rays, are unreliable for a detailed assessment of this relationship. CBCT is regarded as an accurate and trustworthy technique that has been employed in measurements and anatomical analysis [65-66]. In order to spare the patients from needless radiation exposure for research objectives, the retrospective idea in our study aimed to obtain CBCT scans that had previously been performed for other purposes. In order to verify that the maxillary sinus had fully developed skeletally, CBCT images of patients older than 18 were used [67]. In order to ensure an accurate evaluation of the targeted relationship, this study only included fully erupted maxillary premolars with intact roots. Additionally, we excluded premolars with developmental anomalies, root resorption, apicectomy, and the presence of an apical or sinus pathosis, as these may impede the accurate assessment of the roots' proximity to the MSF, as recommended by Ok et al. [68] Gu et al [69] and Shaul Hameed et al [70]. CBCT images were analyzed in the corrected axial, coronal, and sagittal planes, as recommended by von Arx et al [34] and Anter et al [71]. Distance from root tip to maxillary sinus floor were measured by the method of Shahbazian. [32] Different distances between the root and the maxillary sinus floor were presented in this study. There was a significant difference between different distances as P<0.0001, as Type I 169 (51.5%) was significantly the highest, while Type IV 12 (3.69%) was significantly the lowest.Distribution of different distances among number of roots revealed a significant difference between different distances in 1 and 2 roots as P<0.0001. In teeth with one root, Type I was significantly the highest 132 (48.5%), while Type IV was significantly the lowest 12 (4.4%). In two roots, regarding buccal root all cases demonstrated Type I 28 (100%), but in palatal root Type III was significantly the highest 16 (57.1%) while Type II 3 (10.7%) was significantly the lowest.Which means that the palatal roots were closely related to the MSF than buccal ones. These findings were partially consistent with those of Anter et al [72] who found that type IV is the least common. However, type III relationships to MSF are the highest, followed by type I relationships. Our findings are consistent with those of von Arx et al [34] who studied the Swish community. They found, and Kilic et al. further substantiated, that the palatal roots of premolars were closer to the sinus floor than the buccal ones [29]. They also concluded that second premolars had a lower frequency of premolar root protrusion into the maxillary sinus (type IV). Additionally, this study's findings supported those of Tobias et al., who demonstrated that there was typically a relationship between the maxillary second premolar apices and the maxillary sinus of the floor of more than 0.5 mm [31]. Fuentes et al.'s results [73] which also agreed with our findings. Whereas, only 10% of cases showed type IV sinus relation (roots penetrating MSF), they reported that type I was the most common sinus relation in both first and second premolars, accounting for 55.5% of instances, followed by type II (19%). The findings of Ok et al [68] who studied the Turkish population, are comparable to ours. The most common kind of sinus relation seen in these teeth, according to their research, was type I (roots below MSF) in 72% of the maxillary second premolars, followed by type III (roots contacting MSF) in 20% of the teeth, and type IV (roots penetrating MSF) in 8% of the teeth. Nonetheless, a number of studies assessing the relationship between maxillary posterior teeth and the MSF were discovered in the literature. These studies included those by Shokri et al [74] (Iranian population), Bulut et al [16] (Turkish population), Amato et al [75] (Italian population), Gu et al [76] (Chinese population), Razumova et al [76] Chan et al [77] and Kaushik et al [78]. According to the findings of each of these researchers, type I predominated in both premolars, followed by type III and then type IV (roots penetrating MSF), which was also significantly more common in the second premolars than the first. Nino-Barrera et al [30] revealed peculiar findings, indicating that the buccal roots of both bicuspids had a greater incidence of entering the MSF than the palatal one. After reevaluating their approach, we discovered that they had only divided the targeted relation into two types—type 1 for roots that are below the sinus and type 2 for roots that penetrate the sinus—and had not taken into account any other relationship that the root apices might have with the MSF. The reasons for the discrepancies in the results of the studies regarding which root is the closest to and which is the furthest from the MSF can be explained by the variations in the number of patients included in each study, their age ranges, gender distribution, evaluation techniques, and the ethnic makeup of the populations under investigation.

4. Conclusions

In conclusion, single-rooted, single-canal maxillary second premolars are the most common morphology type in the selected Egyptian population, while there may be significant variances in root canal morphology. The majority of the maxillary second premolars were situated considerably near to the maxillary sinus floor, where the highest percentage of type1 sinus relation was observed. In all maxillary second premolars, the palatal roots were more frequently tightly connected to the maxillary sinus floor than the buccal ones.

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