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Original Article

Assessment of Relationship between Maxillary Sinus Floor and Maxillary Posterior Teeth Root Tips Position in a Sample of Egyptian Population using CBCT: An Observational Cross-Sectional Study

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Abstract

Aim: This research was conducted to assess the relationship between maxillary sinus floor and the maxillary posterior root tips position in a Sample of Egyptian Population using CBCT.

Subjects and methods: This cross-sectional study evaluated 144 maxillary premolars and 144 maxillary molars from 41 CBCT scans of 19 male and 22 female patients according to certain eligibility criteria. Image analysis was performed on axial, corrected coronal and corrected sagittal images using **Planmeca Romexis® Viewer software**. The vertical relationship between maxillary sinuses and maxillary premolars was assessed according to Razumova et al., 2019 classification, while the vertical relationship between maxillary sinuses and maxillary molars was assessed according to Kwak et al., 2004 classification. Inter and intra observer agreement were done using Kappa statistics.

Results: Most common vertical relationship between **all maxillary premolars** and maxillary sinus was Type I while most common vertical relationship for **all maxillary molars** was Type II. **The largest distance** was found in first premolars' buccal roots while **the smallest distance** was found in second molars' mesio-buccal roots. There was a significant inverse correlation between age and vertical relationship classes of only 2nd molar roots.

Conclusion: Type I vertical relationship was the most common relationship between all maxillary premolars and MSF while Type II vertical relationship was the most common relationship for all maxillary molars. The largest distance was found in first premolars' buccal roots while the smallest distance was found in second molars' mesio-buccal roots. The lower the age is the closer are the maxillary 2nd molar roots to the MSF.

Keywords: maxillary sinus floor (MSF), maxillary molars, maxillary premolars, CBCT, Relationship

Introduction

The Maxillary Sinus (MS) is the largest and the first sinus to develop in the human body. Growth of the sinus begins in the intrauterine period of life, and reaches its maximum size and forms the shape of a pyramid with time of the third molar eruption or approximately at the age of 21 years.

The mature maxillary sinus extension is changeable. In almost half of the general population, the maxillary sinus floor expands between adjacent teeth or individual roots, producing elevations in the antral surface, usually referred to as 'hillocks'. [1,2]

In addition, sometimes roots of the maxillary posterior teeth were found to be in an intimate relationship or may even extend into the maxillary sinus.[3] When this the case, bacteria from infected periapical tissue or periapical disease may extend into the MS which may then develop acute or chronic maxillary sinusitis. [4,5] Therefore, full knowledge of the proximity of the maxillary posterior teeth root apices to the maxillary sinus floor (MSF) is a mandatory step prior to some procedures as tooth extraction, implant placement and endodontic treatment to avoid over-instrumentation or over-filling as this may result in blow-out of infection. [6]

During routine dental visits, the state of the maxillary posterior teeth and their relation to the maxillary sinus is usually assessed on periapical and panoramic radiographs. However, these radiographs are 2-D and do not assess the actual relation between sinus floor and adjacent teeth. [7]

For proper assessment of this relation, computed tomography (CT) was considered to be the gold standard for sinus diagnosis. [8,9] However, recently, cone beam computed tomography (CBCT) is being extensively employed in oral and maxillofacial region as it offers numerous advantages over traditional CT since it provides comparable image quality at reduced dose, cost and scan time. [10,11] The use of CBCT to evaluate the presence and possible spread of infection from the periapical area to the MSF provided quick radiological diagnosis and allowed superior treatment options and diminished the possibility of complications. [12-15]

Numerous 3-D radiographic studies of the maxillofacial region showed intimate relation and apical protrusion of the maxillary root apices into the MS but with significant variation between populations. [16,17]

Bearing in mind the individual variations of position between different maxillary posterior teeth, this study aimed to assess the relationship between maxillary sinus floor and the maxillary posterior root tips position in a sample of Egyptian population using cone-beam computed tomography (CBCT).

Subjects and Methods

Study design and setting:

This study design is an observational cross-sectional retrospective study that assessed CBCT scans for Egyptian patients that were collected from the database available at the Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Cairo University, Cairo, Egypt. The collected CBCT scans were taken as a part of the patients' dental examination, diagnosis and/or treatment planning during the period from 2021-2022.

Sample size calculation and Medical Biostatistics Unit approval:

Sample size calculation was performed using the G. Power 3.19.2 software. Based upon the results of **Estrela, C et al., 2016,**[18] the primary outcome (root tips position of maxillary premolars versus maxillary molars) was appropriate to be 33 teeth for each tooth group (teeth groups are: 1st premolar,2nd premolar,1st molar and 2nd molar) (total 132 teeth (4 groups)), the power is 80% and α error probability = 0.05. The sample size calculation was approved by Medical Biostatistics Unit, Faculty of Dentistry, Cairo University on 19/4/2021.

According to sample size calculation, 132 teeth

were appropriate for the primary outcome. However, along the process, 144 teeth were reviewed to fulfill the inclusion criteria of scans for patients with first and second maxillary premolars and first and second maxillary molars present at least on one side. Subjects were classified according to age categories into 3 groups: young age (20 – 30 years); middle age (31 – 40 years) and elderly (over 40 years).

Study criteria:

Inclusion criteria where patients' age should be from 20 to 70 years and with first and second maxillary premolars and first and second maxillary molars present at least on one side (fully erupted teeth and fully formed apices). CBCT scans taken for pre-evaluation of endodontic treatment, implant placement, impacted teeth removal, obstructive sleep apnea treatment, pre-orthodontic or pre-prosthetic evaluation and should be with a good quality. Exclusion criteria were CBCT scans with missing maxillary posterior teeth, history of maxillary sinus operation (including sinus floor elevation) and with sign or history of non-odontogenic sinusitis, including air-fluid level, thickening of all the sinus walls and maxillary sinus polyps. Furthermore, patients with syndromes, congenital or developmental anomalies, bone disease and with traumatic injuries to the maxillofacial region were excluded as these may hinder the accurate assessment of the targeted relation.

Image acquisition and analysis:

The selected CBCT scans were all performed using **Planmeca ProMax® 3D Mid** (Planmeca OY, Helsinki, Finland) CBCT machine. All CBCT images were acquired in a digital DICOM format, and they were all imaged using 90 kVp, 8 mA, a maximum of 400 µm voxel size, and a field of view 4 × 5 or 16 × 10 cm. The CBCT images were then imported to **Planmeca Romexis® Viewer software** (Romexis version 4.6.0.R; Planmeca OY, Helsinki, Finland).

All scans were analyzed in the three orthogonal planes: axial, coronal and sagittal as several outcomes were being assessed. The scans were corrected and adjusted for each tooth independently according to its own alignment. CBCT-corrected sagittal and coronal images were created by adjusting both sagittal and coronal reference lines to be passing parallel to the long axis of the root under investigation and through its center; then these images were used for assessment of the relation of maxillary posterior teeth root tips to the MSF. Further confirmation of the assessed relationship was gained from the corrected CBCT axial cut after adjusting the axial reference line to pass through the most apical part of the root on both coronal and sagittal images. The anatomic relation between the maxillary sinus floor and the tips of maxillary multi-rooted and single rooted posterior teeth were assessed for each tooth individually. This relation was evaluated in the examined scans by using the measuring tools of the Romexis software **Figure (1).**

Images were analyzed to observe the following variables:

1. **<u>Relation between maxillary sinus floor and root tips position of maxillary premolars:</u>**

This categorical assessment was evaluated on CBCT corrected sagittal cuts and then checked on corrected coronal cuts and was based on a classification proposed by **Razumova et al., 2019** [19] who suggested three types for the targeted relationship **(Figure (2)):**

Type I: the inferior wall of the MS floor is located above the root apex.

Type II: the root apex touches the inferior wall of the MS.

Type III: an apical protrusion of the root apex is observed over the inferior wall of the MS.

2. **<u>Relation between maxillary sinus floor and root tips position of maxillary molars:</u>**

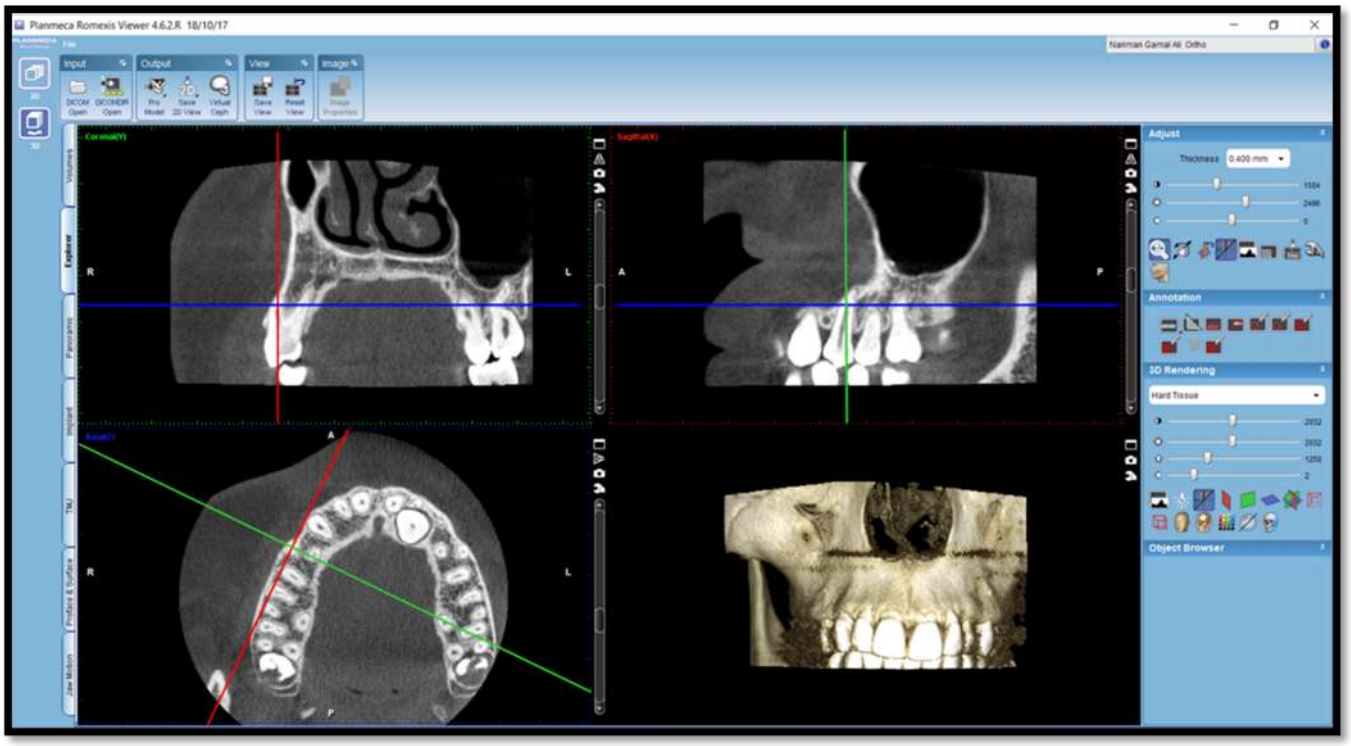

Figure (1): Planmeca Romexis Viewer window showing how to creat the corrected sagittal and coronal cuts from reference lines on axial cut.

This assessment was evaluated on CBCT corrected coronal cuts and image adjustment procedure was similar to what was described previously for assessment of premolar roots and recorded according **to Kwak et al., 2004** [20] **classification** as follows**:**

Type I: the inferior wall of the MS floor is located above the root apex of the buccal and palatal roots **(Figure (3)).**

Type II: the inferior wall of the MS is located below the level connecting the buccal and palatal root apices without an apical protrusion over the MS **(Figure (3)).**

Type III: an apical protrusion of the buccal root apex is observed over the inferior wall of the MS **(Figure (3)).**

Type IV: an apical protrusion of the palatal root apex is observed over the inferior wall of the MS **(Figure (3)).**

Type V: apical protrusions of the buccal and palatal root apices are observed over the inferior wall of the MS **(Figure (4)).**

Blinding and inter- and intra-observer agreement:

Images were assessed twice by an investigator **STK** having 5 years of experience in CBCT interpretation with 1-month interval between the two reading sessions to assess the intra-observer reliability. While for the interobserver reliability, the images were analyzed once more by a second investigator having more than 12 years of experience in the same field. Blinding was assured by scans coding and concealing the patients' demographic data from both observers.

Statistical analysis:

Qualitative data were presented as frequencies and percentages. Chi-square and Fisher's Exact tests were used for associations related to qualitative data. Numerical data were presented as mean and standard deviation (SD) values. Kappa statistic and Cronbach's alpha reliability coefficients were used to assess intra- and inter-observer agreement. Agreement values are interpreted as follows; 0 – 0.2: weak agreement, 0.2 – 0.4: fair agreement, 0.4 – 0.6: moderate

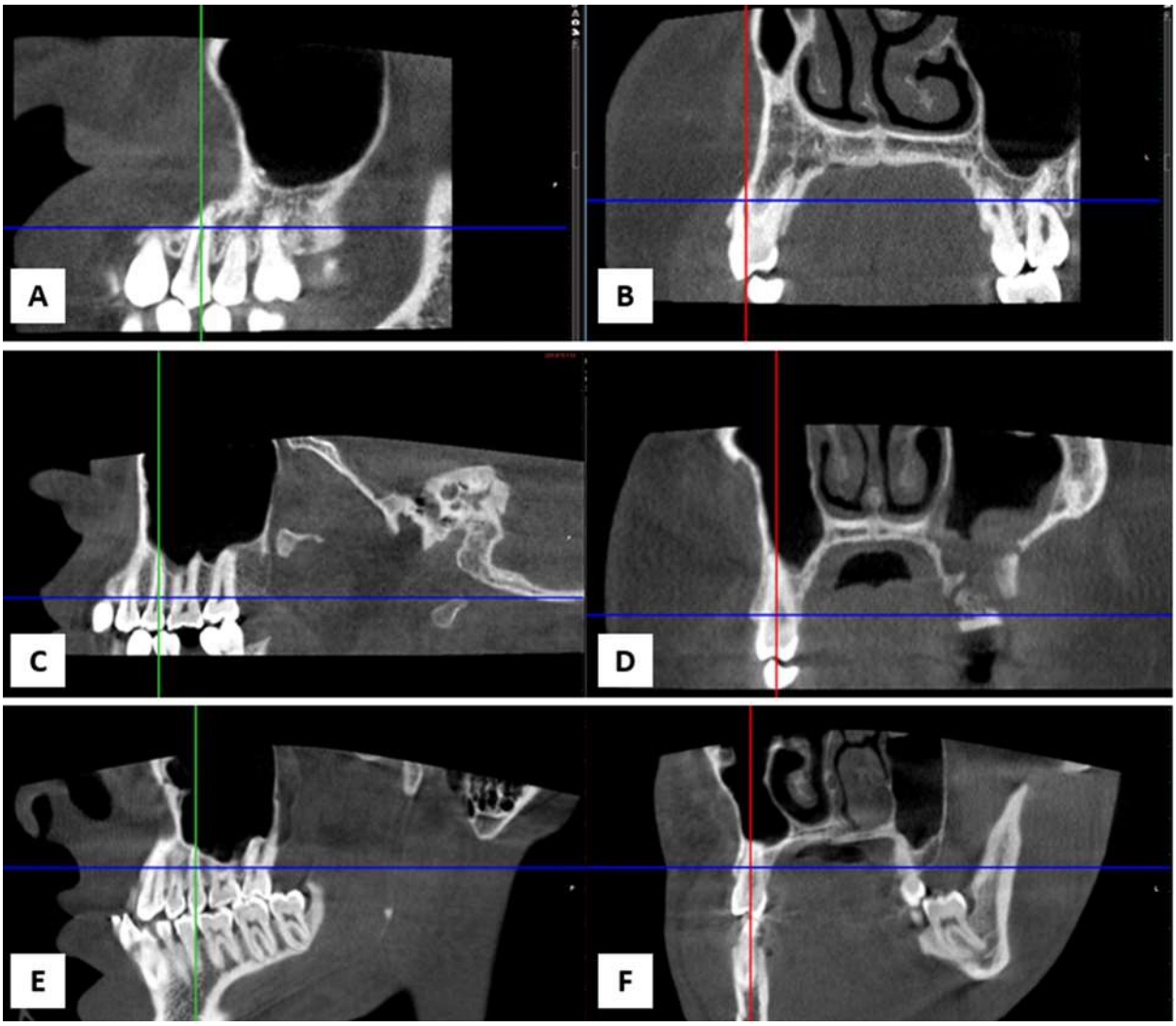

Figure (2): CBCT scan showing, (A) Corrected Sagittal cut and (B) Corrected Coronal cut showing Type I relationship in buccal root of upper right 1st premolar, (C) Corrected Sagittal cut and (D) Corrected Coronal cut showing Type II relationship in upper right 2nd premolar and (E) Corrected Sagittal cut and (F) Corrected Coronal cut showing Type III relationship in buccal root of upper right 2nd premolar.

agreement, 0.6 – 0.8: good agreement, 0.8 – 0.99: very good agreement while a value of 1 indicates perfect agreement. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

RESULTS

The present study was conducted on 41 subjects; 19 males (46.3%) and 22 females (53.7%). The mean (SD) values for age were 32.8 (8.4) years with a minimum of 21 and a maximum of 52 years. Subjects were classified according to age categories into young age (20 – 30 years) representing 39% of the study sample; middle age (31 – 40 years) representing 36.6% of the study sample and elderly (over 40 years) representing 24.4% of the study sample.

Inter- and intra-observer agreement

- There was very good inter-observer agreement regarding all measurements with agreement values ranging from 0.816 to 0.925 **(Table (1)).**

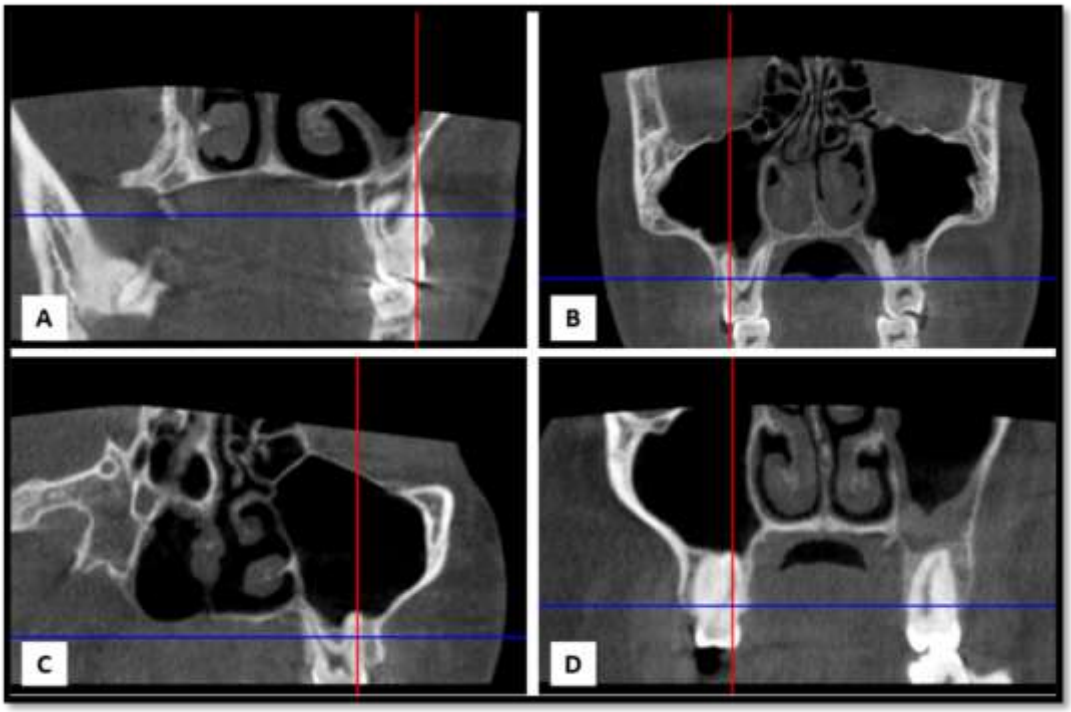

Figure (3): CBCT scan showing, (A) Corrected Coronal cut showing Type I relationship in mesio-buccal and palatal roots of upper left 1st molar, (B) Corrected Coronal cut showing Type II relationship in disto-buccal and palatal roots of upper right 1st molar, (C) Corrected Coronal cut showing Type III relationship in mesio-buccal root of upper left 2nd molar and (D) Corrected Coronal cut showing Type IV relationship in palatal root of upper right 2nd molar.

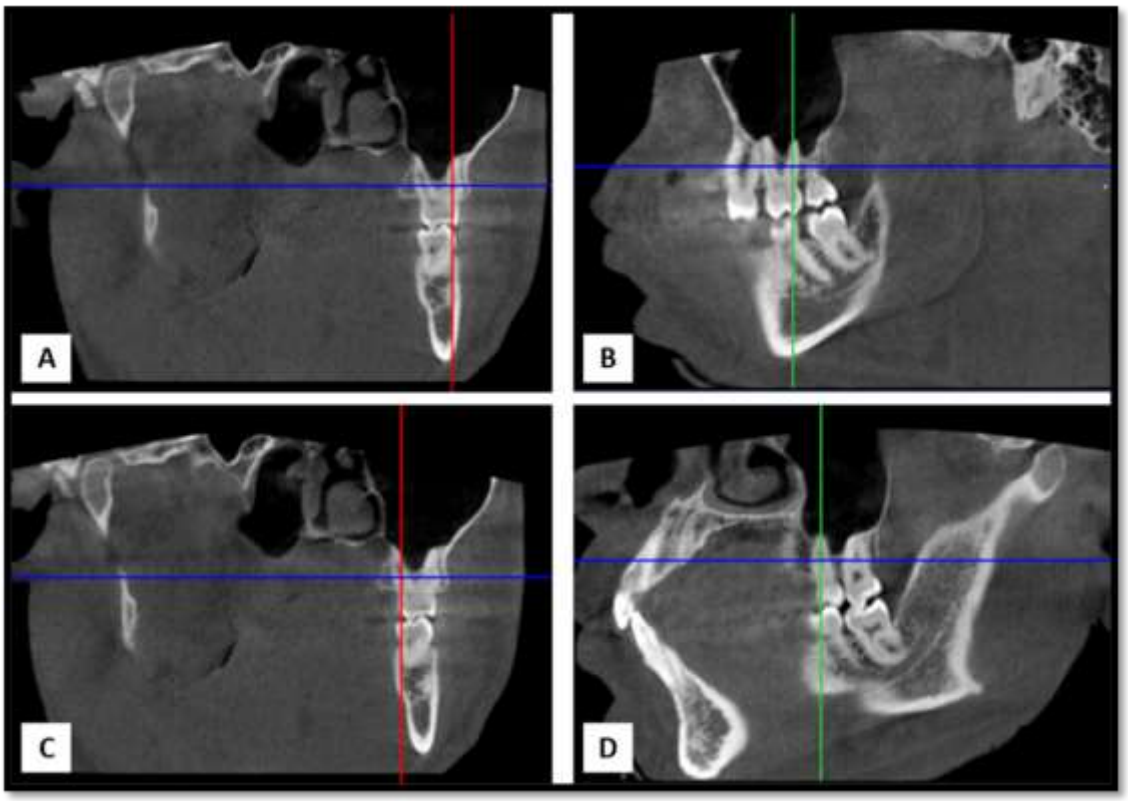

Figure (4): CBCT scan showing, (A) & (C) Corrected Coronal cuts and (B) & (D) Corrected Sagittal cuts showing Type V relationship in buccal and palatal roots of upper left 2nd molar.

- There was also very good intra-observer agreement regarding all measurements with agreement values ranging from 0.829 to 0.940 **(Table (1)).**

1. Vertical relationship between roots of maxillary premolars and maxillary sinus

- **As regards all first premolars with two roots;** the most common relation was Type I (97%) followed by Type II (3%) while none of the roots had Type III. **In young age subjects;** the most common relation was Type I followed by Type II while none of the roots had Type III. **All middle age and elderly subjects** had Type I relationship **(Table (2)).**
- **For first premolars with one root;** there was only one case with Type I relationship **(Table (2)).**
- **As regards all second premolars with two roots;** the most common relation was Type I (70.8%) followed by Type II (22.9%) then Type III (6.3%). **In young age subjects;** the most common relation was Type I followed by Type II then Type III, **while for middle age and elderly subjects,** the most common relation was Type I followed by Type II and none of the roots had Type III **(Table (2)).**
- **As regards all second premolars with one root;** the most common relation was Type I (52.6%) followed by Type II (47.4%) while none of the roots had Type III. **In young age subjects;** Types I and II showed equal prevalence. **In middle age subjects;** the most common relation was Type I followed by Type II and none of the roots had Type III. **For elderly subjects;** the most common relation was Type II followed by Type I and none of the roots had Type III **(Table (2)).**

2. Vertical relationship between roots of maxillary molars and maxillary sinus

- **As regards upper right first molar;** the most common relation was Type II followed by Type I, Type IV, Type V while Type III showed the lowest prevalence **(Table (3)).**
- **For upper right second molar;** the most common relation was Type II followed by Type I, Type V, Type III while Type IV showed the lowest prevalence **(Table (3)).**
- **As regards upper left first and second molars;** the most common relation was Type II followed by Type I then Types III and V with the same prevalence while Type IV showed the lowest prevalence **(Table (3)).**
- **As regards the overall molar relationship;** the most common relation was Type II (53.6%) followed by Type I (24.6%), Type V (10.1%), Type III (7.2%) while Type IV showed the lowest prevalence (4.3%) **(Table (3)).**

3. Vertical relationship between roots of maxillary molars and maxillary sinus among different age groups

As regards first molar, there was no statistically significant association between roots of maxillary molars and maxillary sinus among different age groups, **while for second molar,** there was a statistically significant association between roots of maxillary molars and maxillary sinus among different age groups. The highest prevalence of Type I was found in elderly subjects. The highest prevalence of Types II, III and IV was found in young subjects while the highest prevalence of Type V was found in middle age subjects **(Figure (5)).**

Table (1): Results of Cronbach's alpha and kappa statistic for inter- and intra-observer agreement.

Measurement	Inter-observer	Intra-observer
Distance between root apices and maxillary sinus (Cronbach's alpha)	**0.816**	**0.829**
Relationship between root apices and maxillary sinus (Kappa)	**0.848**	**0.871**
Maxillary sinus floor thickness (Kappa)	**0.882**	**0.916**
Periapical lesion type (Kappa)	**0.925**	**0.940**
Periodontal bone loss type (Kappa)	**0.907**	**0.916**

Table (2): Frequencies (n) and percentages for types of relationship between roots of maxillary premolars and maxillary sinus

Tooth	Age group	Type I		Type II		Type III	
		n	%	n	%	n	%
First premolar (Two roots)	Young age	25	92.6	2	7.4	0	0
	Middle age	23	100	0	0	0	0
	Elderly	17	100	0	0	0	0
	Total	65	97	2	3	0	0
First premolar (One root)	Young age	1	100	0	0	0	0
	Total	1	100	0	0	0	0
Second premolar (Two roots)	Young age	14	73.7	2	10.5	3	15.8
	Middle age	11	68.8	5	31.2	0	0
	Elderly	9	69.2	4	30.8	0	0
	Total	34	70.8	11	22.9	3	6.3
Second premolar (One root)	Young age	4	50	4	50	0	0
	Middle age	5	71.4	2	28.6	0	0
	Elderly	1	25	3	75	0	0
	Total	10	52.6	9	47.4	0	0

Table (3): Frequencies (n) and percentages for types of relationship between roots of maxillary molars and maxillary sinus

Tooth	Number of teeth	Type I		Type II		Type III		Type IV		Type V	
		n	%	n	%	n	%	n	%	n	%
16	34	9	26.5	17	50	1	2.9	4	11.8	3	8.8
17	34	7	20.6	16	47.1	4	11.8	1	2.9	6	17.6
26	35	9	25.7	21	60	2	5.7	1	2.9	2	5.7
27	35	9	25.7	20	57.1	3	8.6	0	0	3	8.6
Total	138	34	24.6	74	53.6	10	7.2	6	4.3	14	10.1

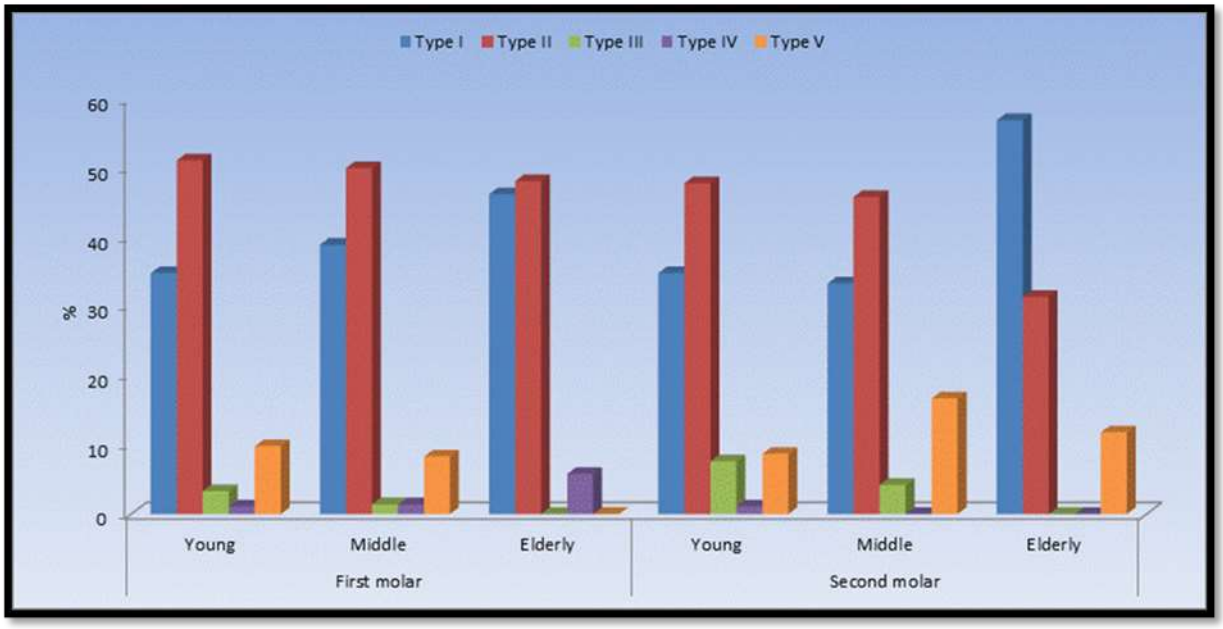

Figure (5): Bar chart representing percentages for the association between types of relationship between roots of maxillary molars and maxillary sinus among different age group.

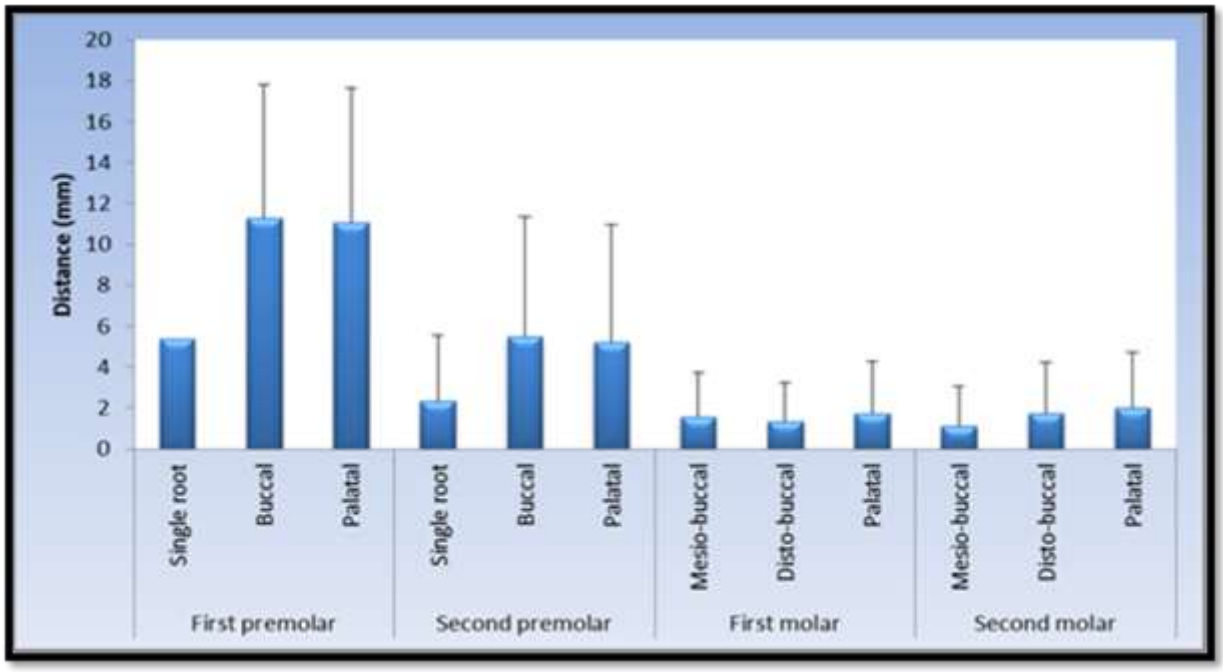

Figure (6): Bar chart representing mean and standard deviation values for the distance between roots of maxillary posterior teeth and maxillary sinus floor.

4. Distance between roots of maxillary posterior teeth and maxillary sinus floor

The largest mean distance was found with the buccal roots of first premolars while the smallest mean distance was found with the mesio-buccal roots of second molars **(Figure (6)).**

Discussion

The floor of the maxillary sinus often expands between the roots of the posterior teeth or extends beneath the posterior teeth roots, resulting in a close proximity of roots and sinus. Radiographically, the roots may appear penetrating the floor of the maxillary sinus and protruding into the antrum, but, in fact, it is the maxillary sinus that has extended around the roots (pneumatization of alveolar process).[21] The sinus recesses require attentive observation in the region before some dental procedures, especially in placement of dental implants, endodontic procedures, and extractions. Lack of thorough knowledge of the close proximity between the MSF and root apex adds to the complexity of dental procedures as it facilitates spreading of the bacterial infection from a periapical disease to the maxillary sinus causing mucositis and odontogenic maxillary sinusitis. Moreover, complications resulting from the introduction of endodontic instruments, intracanal medicaments, root filling material, extraction or endo-surgery procedures of roots closely related to the sinus may cause iatrogenic perforation of the MSF and formation of oroantral fistula and sinus membrane thickening. [10, 22-24]

As far as we know, and based upon a meticulous and thorough systematic search in different databases, no studies were found assessing these outcomes collectively in maxillary premolars and molars in an Egyptian population. Hence, our study was thought to assess the relationship of maxillary sinus and posterior teeth root tips position in a sample of Egyptian population aiming to improve the preoperative treatment planning and to avoid complications.

CBCT was the modality selected in this study, as it was proven by many previous studies to be the gold standard of assessing sinus root relation. Retrospective concept in our study was meant to get CBCT scans that were already done earlier for different purposes to avoid exposing the patients to unneeded radiation dose for the research

purpose. The sample size was calculated statistically prior to conducting the study based on **Estrela et al., 2016** [18] to ensure that the obtained results were true, valid and not coincidental. The present study was conducted on 41 subjects; 19 males (46.3%) and 22 females (53.7%) to correlate the outcomes with gender. We selected our sample size based on certain eligibility criteria as recommended by **Huang et al., 2021;**[25] **Shaul Hameed et al., 2021;**[16] **Razumova et al., 2019;**[19] **von Arx et al., 2014**[21] **and Mahnaz Sheikhi, 2013.**[26] CBCT scans of patients above 20 years were included to ensure complete skeletal development of the maxillary sinus.[27] This study involved only fully erupted teeth and fully formed apices for patients with first and second maxillary premolars and first and second maxillary molars present at least on one side.

CBCT images were analyzed in corrected axial, coronal and sagittal planes to detect the anatomic relation between maxillary sinus floor and tips of maxillary multi-rooted and one rooted posterior teeth, the distance between maxillary sinus floor and root tips of posterior teeth as recommended by **Morsy et al., 2022;**[22] **Aksoy & Orhan, 2019;**[28] **Anter et al., 2019;**[29] **Razumova et al., 2019;**[19] **Asthana et al., 2015;**[30] **Goller-Bulut et al., 2015;**[31] **Mahnaz Sheikhi, 2013.**[26] This relation was evaluated in the examined scans by using the measuring tools available in the viewer software.

The assessment of the vertical relationship between maxillary sinus floor and maxillary premolars was categorized according to **Razumova et al., 2019** [19] and the assessment of the anatomic relationship between maxillary sinus floor and maxillary molars was performed based on a classification described by **Kilic et al., 2010.**[1] The same classification was also used by several investigations such as **Shaul Hameed et al., 2021;**[16] **Razumova et al., 2019;**[19] **Gu et al., 2018;**[23] **Estrela et al., 2016;**[18] **Pagin et al., 2013;**[24] **Jung & Cho, 2012**[32] **and J. A. Eberhardt et al., 1992.** [33]

Regarding the vertical relationship between maxillary premolars root tips and maxillary sinus floor, the results of this study revealed that the most common relation **of maxillary first premolars with two roots** was Type I (the inferior wall of the MS floor is located above the root apex) followed by Type II (the root apex touches the inferior wall of the MS) while none of the roots had Type III sinus relation (an apical protrusion of the root apex is observed over the inferior wall of the MS). On the other side, **for maxillary first premolars with one root,** there was only one case with Type I sinus relation. The fact that most 1st premolars showed Type I could be attributed to that most of 1st premolars are positioned more anteriorly and close to the inverted Y-shape of Ennis where the maxillary sinus floor curves upward to intersect with the lateral wall of the nasal cavity. Additionally, this can be due to the fact that the cortical thickness of the MSF is greatest at the first premolar region as stated by **Estrela et al., 2016.**[18] Regarding **all maxillary second premolars with two roots;** Type I sinus relation showed the highest prevalence followed by Type II then Type III relation. For **all maxillary second premolars with one root;** the most common relation was Type I followed by Type II and none of the roots showed Types III sinus relation.

In agreement with our results, came **Razumova et al., 2019** [19] who conducted their study to assess the relationship between the MS floor and the root apices of the posterior teeth using cone-beam computed tomography (CBCT) scanning in a Russian population and from whom we adopted the classification. **Razumova et al., 2019** [19] were assessing the relationship between two-rooted maxillary premolars and MSF based on a classification proposed by **Kwak et al., 2004** and for one-rooted teeth they based on his own classification and they reported that Type I sinus relation was the most common relation in the first and second premolar region.

Additionally, a study by **Shokri et al., 2015** [10] on an Iranian population who analyzed 110 CBCT scans to assess the relationship between the maxillary premolars roots and the MSF based on a classification proposed by **Jung & Cho, 2012** [32] revealed that Type 0 (the maxillary sinus floor is

located above the root tip) was mostly observed in the first and second premolars with (95.3%) and (67.6%) prevalence respectively. Also **Fry et al., 2016** [34] who conducted their study on an Indian population found that Type 0 was commonly seen in first and second premolars.

Our results were also similar to those of **Morsy et al., 2022** [22] who conducted their study to assess the relationship between maxillary premolar roots and maxillary sinus floor in an Egyptian population. **Morsy et al., 2022** [22] were assessing the relationship between the maxillary premolar roots and the MSF based on a classification proposed by **Kilic et al., 2010** and concluded that the highest prevalence among maxillary first premolars (single-, double-, and triple-rooted) exhibited"No relation"to the MSF whereas type 3 sinus relation (roots below the MSF) recorded the second position followed by type 2 (roots contacting the MSF) and finally type 1 (roots penetrating MSF) that was observed in only one single-rooted upper first premolar. Regarding the maxillary second premolars, type 2 sinus relation showed the highest prevalence among the single- and double-rooted second premolars followed by type 3. "No relation" recorded the third position in single-rooted maxillary second premolars which were almost similar to our recorded values.

Different results were reported by **Nino-Barrera et al., 2018** [35] in a Colombian population. They reported that both bicuspids showed higher incidence of penetrating the MSF. However, on revising their methodology, we found that they classified the targeted relation into two types only (type 1 representing roots below the sinus and type 2 for roots penetrating the sinus).

Regarding the effect of age as a confounder on the vertical relationship between maxillary premolars root tips and maxillary sinus floor, this study showed that for all first premolars with two roots, the most common relation in young age subjects (20 – 30 years) was Type I (the inferior wall of the MS floor is located above the root apex) followed by Type II (the root apex touches the inferior wall of the MS) while none of the roots had Type III sinus relation (an apical protrusion of the root apex is observed over the inferior wall of the MS). However, all middle age (31 – 40 years) and elderly (40 – 70 years) subjects had Type I relationship. **For all second premolars with two roots,** in all age groups the most common relation was Type I followed by Type II. Type III was only found in young age subjects. **For all second premolars with one root,** in young age subjects, Types I and II showed equal prevalence. In middle age subjects, the most common relation was Type I followed by Type II and none of the roots had Type III. For elderly subjects, the most common relation was Type II followed by Type I and none of the roots had Type III. These results came in agreement with those of **Razumova et al., 2019** [19] who reported that Type I was the most common relation between maxillary sinus floor and maxillary premolars in all age groups.

Regarding the vertical relationship between maxillary molars root tips and maxillary sinus floor, the results of this study showed that the most common relation was Type II (53.6%) followed by Type I (24.6%), Type V (10.1%), Type III (7.2%), while Type IV showed the least prevalence (4.3%).

In accordance with our results, **Razumova et al., 2019** [19] who conducted their study on a Russian population reported that type II was seen commonly in the first and second molars among different age groups with (64.6%) and (61.7%) respectively and that Type V sinus relation was observed in (5.5%) for the second molars. Also, **Shaul Hameed et al., 2021** [16] reported that Type II vertical relationship is the most common in a Saudi population (62–70%). Additionally, **Estrela et al., 2016** [18] reported similar results in a Brazilian population.

On the other hand, the vertical relationship mostly observed in the studies concluded by **Kwak et al., 2004** [20] **(**Korean population**) and Kilic et al., 2010** [1] **(**Turkish population**)** was Type I vertical relation. This could be due to anatomical differences and variation in the studied populations. However, a common feature in Type I and Type II is the absence of protrusion of the

roots into the sinus floor. On the contrary, **Jung & Cho, 2012** [32] **(**Korean population**)** showed that projection of the roots into the MS was the most commonly observed vertical relationship. Again, this can be attributed to the difference in the studied populations.

Effect of age as a confounder on the vertical relationship between maxillary molar root tips and maxillary sinus floor, this study found no statistically significant association between roots of **maxillary first molars** and maxillary sinus among different age groups. However, **for all second molars,** there was a statistically significant association between roots of maxillary second molars and maxillary sinus among different age groups. The highest prevalence of Type I was found in elderly subjects (40 – 70 years) while the highest prevalence of Types II, III and IV was found in young subjects (20 – 30 years). The highest prevalence of Type V was found in middle-age subjects (31 – 40 years). When we compared our results with the results of **Anter et al., 2019** [29] study that also conducted on the Egyptian population, we find that our results are similar to theirs except for exclusive in maxillary 1st molars only as they showed that age was a significant predictor for the vertical relationship between root apices of maxillary 1st molar and the MSF, as there was an inverse correlation between the age and vertical relationship types, as type 0 with less sinus approximation was more frequent in older subjects while type 3 with MSF invasion was more common in younger subjects. Also, results of **Razumova et al., 2019** [19] were in partial agreement with the results of this study as they stated that Type I was found in older age group which was similar to the results of the current study. However, they reported that Type I was also found in middle-age and young subjects.

On the other hand, **Pagin et al., 2013** [24] reported that the most common relation between maxillary sinus floor and maxillary molars in elderly subjects was Type II. This could be due to the difference in the studied populations.

Regarding the distance between roots of maxillary posterior teeth and maxillary sinus floor, the results of the current study showed that the molar roots are closer to the MSF than premolars. The largest mean distance to the MSF was found related to the buccal roots of first premolars while the smallest mean distance was found related to the mesio-buccal roots of second molars.

The results of the present study are in agreement with some previous studies that used both CT and CBCT scans. **Eberhardt et al. 1992** [33] measured the distance between the root apices of posterior teeth and the MSF by CT and obtained results similar to the present study. In accordance, **Jung & Cho, 2012** [32] analyzed the relationship of the maxillary molars and adjacent structures by CBCT and found that the shortest distance between the root apex and the MS was in the mesio-buccal root of the second molars. Also, **Pagin et al., 2013** [24] evaluated qualitatively the close relationship between the maxillary sinus floor and the root apices of posterior teeth in a Brazilian population using CBCT images. They stated that the mesio-buccal root of the second molar was frequently found in close proximity to the maxillary sinus floor. With regards to the largest distances, the results of the present study showed that the root apices of first premolars are frequently far away from the maxillary sinus floor, which agrees with the study conducted by **Kilic et al., 2010.** [1] Further support came from other studies including those of **Razumova et al., 2019** [19] **and Estrela et al., 2016** [18] who reached almost the same results regarding the distance between roots of maxillary posterior teeth and maxillary sinus floor. Also, our results were similar to those of **Anter et al., 2019** [29] who conducted their study to assess the proximity between the roots of maxillary molars and maxillary sinus floor using CBCT in an Egyptian population based on a classification proposed by **Jung et al., 2009** and concluded that the 1st molar was the least close molar to the MSF with the highest prevalence of class 0 in all of mesio-buccal, disto-buccal & palatal roots, while the 2nd molars showed the highest prevalence of class (3) among both mesio-buccal & disto-buccal roots, and the highest prevalence of class (2) among palatal roots.

However, some other studies showed that the disto-buccal root of the second molar was the nearest root apex to the maxillary sinus floor. For example, **Shaul Hameed et al., 2021** [16] on a Saudi Arabian population stated that the apices of the disto-buccal root of the maxillary right second molar were nearest to the maxillary sinus floor. Also, **Kwak et al., 2004** [20] who used CT on a Korean population & **Kilic et al., 2010** [1] who used CBCT on a Turkish population showed that the disto-buccal root of the second molar was closest to the sinus floor. On the other hand, **Yoshimine et al., 2012** [36] analyzed the anatomical characteristics of premolars, molars and maxillary sinus for dental implant on a Japanese population using CBCT and revealed that the shortest distance was found in relation to the palatal root of the first molar. Again, these variations could be attributed to the differences in the number of patients included in both studies, their gender distribution, their age ranges, the evaluation method and the ethnicity characteristics of the examined populations.

In this study, the classification of **Razumova et al., 2019** [19] was used for both single and double-rooted maxillary premolars, although it would have been better to use **Kwak et al., 2004** [20] classification for premolars with two roots. However, despite this difference in method between this study and the study of **Razumova et al., 2019** [19], it did not affect the results because the majority of the Egyptian population only has Type I and Type II of the classification, and we did not address any other types that penetrates the maxillary sinus floor except in three cases only, and they were of Type III.

Conclusion

In the investigated Egyptian subjects:

1- Type I vertical relationship was the most common relationship between **all maxillary premolars** and maxillary sinus floor while Type II vertical relationship was the most common relationship between **all maxillary molars** and maxillary sinus floor.
2- The molar roots are closer to the maxillary sinus floor than premolars as **the largest distance** was found in the buccal roots of first premolars while **the smallest distance** was found in the mesio-buccal roots of second molars.
3- The lower the age is the closer are the maxillary 2nd molar roots to the MSF.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Ethical policy and Institutional Review Board statement

This study protocol was approved by the ethical committee of the Faculty of Dentistry, Cairo University, Egypt (approval date April 27, 2021). The trial is registered on clinicaltrials.gov under identifier: NCT04903418.

Patient declaration of consent

Not applicable.

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