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Research Paper: The Relation Between Maxillary Sinus Floor and Posterior Maxillary Teeth Roots Using Panoramic and Cone Beam Computed Tomography

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ABSTRACT

Introduction: Understanding the anatomical and pathological relationships between posterior teeth or edentulous area with maxillary sinus is essential for diagnosis and treatment management.The present study aimed to assess the relationship between maxillary sinus floor and posterior teeth roots using panoramic radiography and Cone Beam Computed Tomography (CBCT).

Materials and Methods: In this analytical cross-sectional study, 440 maxillary first and second premolars, and first and second molars of 55 patients were selected by the census method. The patients were referred to Sajad Maxillofacial Radiology and Navabazam Maxillofacial Surgery Clinic in Yazd City from 2011 to 2015. The relationship between each root and maxillary sinus floor was examined by oral radiologist and trained dentistry student using CBCT and panoramic radiography. To check the reproducibility of the first observer, a second observer examined 20 radiographs daily for five days and in random orders. No difference was found between the observers. The collected data were analyzed by ANOVA, Chi square, Fisher's exact test, and t test using SPSS ($P \leq 0.05$).

Results: The agreement between CBCT and panoramic radiographs in determining root form was measured with kappa, which was found as 0.549 (P=0.0001). This implies that CBCT and panoramic radiographs showed an agreement in determining the position of maxillary sinus floor and posterior teeth roots. The difference between calculated mean (SD) distances of the two methods was 0.74(2.92) mm (P=0.0001). This indicates that the measurements by panoramic radiographs differ from CBCT.

Conclusion: Our study results supports use of CBCT to establish the exact correlation between maxillary sinus floor and posterior teeth roots, especially in classification 3 (projected in panoramic radiographs) for reducing damages and infection transmission.

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1. Introduction

The maxillary sinus is the first of the paranasal sinuses to develop, and its growth ends with the eruption of the third molars at approximately 20 years of age. The floor of the sinus is formed by the alveolar process of the maxilla [1]. The sinus is variable in extension towards the alveolar ridge. In about half of the population, the sinus floor extends between adjacent teeth or individual roots, creating elevations in the antral surface, commonly referred to as "hillocks" [2], or projection of root apex into the sinus. Histologic sections indicate that most roots, radiographically extended into the sinus, are separated from the sinus by a thin cortical layer, and in 14%-28% of the cases perforation occur [3].

Understanding the anatomical and pathological relationships between posterior teeth or edentulous area and maxillary sinus is essential for diagnosis and treatment management [4]. The close relationship between maxillary sinus and related tooth position of the maxillary posterior teeth may lead to unwanted oroantral connection during extraction of posterior teeth [5, 6]. The relative position of dental roots to inferior sinus wall is known to influence orthodontic tooth movement [7]. A periapical or periodontal infection of the upper premolars and molars may spread beyond the confines of the supporting dental tissue into the maxillary sinus. Protruded roots into the sinus may cause post-extraction pneumatization, which reduces the amount of bone available at the implant or denture site [8].

The relative position of the maxillary posterior teeth roots can be examined by different 2D and 3D imaging techniques such as panoramic radiography, Computerized Tomography (CT), and Cone-Beam Computed Tomography (CBCT). Panoramic radiography shows mandible, maxilla, and the floor of maxillary sinus [2]. Some advantages of this method include disclosing many facial structures, cost effectiveness, low radiation, and easy accessibility [3]. However, as a 2D technique, it may have limitations due to superimposition of anatomical structures, horizontal and vertical magnifications (10%-33%), and lack of cross-sectional information [2].

3D techniques such as CT and CBCT overcome these limitations and provide multiplanar images of facial structures. Although CT is currently being used as a reference for sinonasal imaging, its high radiation dose and harder accessibility limits its use [9, 10]. CBCT provides isotropic 3D information with lower dose and price, and shows maxillary sinus and related structures with a higher quality compared with CT. Its accessibility is growing too [11].

Various studies have classified the relationship between posterior teeth roots and the inferior sinus wall as vertical (in 2D and 3D techniques) and horizontal (in 3D technique) [2]. These studies compare panoramic imaging with 3D techniques such as CT. Panoramic imaging is routinely used prior to prosthetic and implant surgeries in the posterior maxilla. Shahbazian et al. [4]in their study assessed whether and how the information obtained by means of CBCT on maxillary posterior teeth differs from that obtained by panoramic radiography. It was of major clinical importance that the 3D nature of CBCT imaging allowed a better assessment of the relationship between the maxillary sinus and posterior root apices compared with the low detection on panoramic radiographs.

In 2014, Bashizadehfakhar et al. found that the majority of roots projected on the sinus cavity in panoramic imaging had no vertical protrusion in CBCT cuts. According to these findings, using CBCT is recommended. It is thus important to understand how a 3D view is different from a 2D radiograph in the posterior maxilla. The purpose of this study was to determine any relationship between maxillary sinus floor and maxillary posterior teeth roots using panoramic radiographs and CBCT images in selected Yazd population.

2. Materials and Methods

This is a cross-sectional study. Based on a similar study, a total of 440 maxillary first and second premolars, and first and second molars (110 each) of patients referred to Navabazam Maxillofacial Surgery and Sajad Maxillofacial Radiology Clinics in Yazd City in the period of 2010-2014 [4]. Patients were selected by the census method and met the following criteria: 1. There must have both CBCT and panoramic images of the mentioned teeth; 2. Time interval between images must be no longer than three months; and 3. Quality of the root apex and sinus floor must be appropriate in both images.

CBCT images were taken using CBCT machine (Planmeca, Helsinki, Finland) with exposure parameters of 70-90 KVP, 14 s, 10-12 mA, and field of view of 8*8 cm. Coronal, axial, and sagittal sections were provided by the software. Digital panoramic radiography of the same patients was performed by Planmeca machine (Planmeca, Helsinki, Finland). Panoramic images were analyzed by Planmeca Romexis 2.9.2. R and CBCT images were processed by the same software.

Patients with any type of lesions in the maxillary posterior teeth were excluded from the study. Images were grouped according to the relative position of the root (each root separately for multi rooted teeth) to the maxillary sinus floor as follows (Figure 1): 0. Root is not in contact with the cortical borders of the sinus; 1. An inferiorly curving maxillary sinus floor and the root is in contact with the cortical borders of the sinus; 2. An inferiorly curving maxillary sinus floor and the root is projecting laterally on the sinus cavity but its apex is outside the sinus boundaries; 3. An inferiorly curving maxillary sinus floor and the root apex is projecting in the sinus cavity; and 4. A superiorly curving maxillary sinus floor which covers part or the entire tooth root.

In cases of 0, 3, and 4, the length of the apical part of the root superior to the sinus inferior wall was measured in both radiographic techniques (Figure 1, 2). Cases with apex being inferior to the sinus were given positive numbers. Cases with apex being superior to the sinus were given negative numbers (groups 3 and 4). In groups 3 and 4, using the panoramic radiograph, the measurement represents the radiographic projection of the root on the sinus cavity, and in the CT it represents the protrusion of the root into the sinus.

In CBCT scans, the measurement was done according to the distance between root tip and the cortical inferior wall in accordance with the longitudinal axis (Figure 3). Since CBCT can project buccolingual dimension of the roots, we classified the relationship between teeth roots and the sinus floor in groups 2 and 3 as follows: B. The farthest point of the sinus floor is located at the buccal side; BP. The farthest point of the sinus floor is located between buccal and palatal roots; and P. The farthest point of the sinus floor is located at the palatal side.

The distance between buccal and palatal cortical bones covering the roots and teeth roots below the bifurcation area in multi root teeth and the middle area of root in single-rooted teeth was measured in the CBCT section. All panoramic investigations were done by a trained dentistry student. To check the reproducibility of the first observer, a second observer examined 20 radiographs daily for five days and in random orders. No difference was found between these observers. The approval code was 655. The collected data were analyzed by ANOVA, Chi square test, Fisher's exact test, and t test using SPSS.

3. Results

This study was conducted on 55 patients. The relationships between 817 roots of the first and second premolars, and first and second molars with the maxillary sinus floor were assessed and accordingly classified (Table 1). Mean (SD) age of the subjects was 37.24(12.6) years, ranging from 14 to 62 years. Among the subjects, 26(47.3%) were males and 29(52.7%) were females. In 50.6%, was located at the right and in 49.4%, was located at the left side. The agreement between images was calculated by kappa test. Panoramic radiographs are relatively in good agreement with CBCT in showing the relative position of roots with maxillary sinus (Table 2).

Considering the classification of relationship between posterior teeth roots and sinus floor, panoramic and CBCT techniques led to similar results (Table 3). Chi-square analysis showed more agreement between panoramic and CBCT images in determining root classification in the first and second premolars compared with second and first molars, and the obtained data were statistically significant (Table 4).

The correlation coefficient of distance in panoramic radiograph to CBCT image showed a significantly positive correlation ($P<0.001$). The difference of mean distance between the two radiographic techniques was significant ($P<0.001$). Thus, the results of the two techniques cannot be considered similar (Table 5). Statistical analysis indicated that tooth number does not impact the distance between sinus floor and root, and the difference was not significant ($P=0.033$) (Table 6). Table 7 presents the mean distance between root and sinus floor divided by root type and radiography technique. Table 8 presents the mean distance from lingual and buccal cortical bone divided by root type.

4. Discussion

This study compared the relation between maxillary sinus floor and maxillary posterior teeth roots using panoramic and CBCT imaging techniques. Considering the routine use of panoramic imaging to assess the relationship between teeth roots and the sinus and the importance of this relationship in orthodontics, surgery, implants, augmentation, sinus lift, extension of pulp diseases into sinus, and sinus pneumatization, we compared the accuracy of panoramic imaging method with the more comprehensive images of CBCT. Friesfield et al. suggested a classification of the relationship between the teeth and sinus. However, their method was used only for the first molar and did not include the topographic position of the maxillary sinus and lateral position of the roots [12].

Kwak et al. suggested a more comprehensive classification, but it was only useful for CT [13]. The current study

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Table 1. Frequency distribution of teeth divided by tooth type and radiography technique

Tooth Type	Radiograph	Classification					Total
		0	1	2	3	4	
1st premolar	Panoramic	101	15	39	4	2	161
	CBCT	105	15	36	3	2	
2nd premolar	Panoramic	54	27	15	6	1	103
	CBCT	60	27	13	2	1	
1st molar	Panoramic	114	90	0	89	10	303
	CBCT	115	136	3	41	8	
2nd molar	Panoramic	76	81	12	44	37	250
	CBCT	72	117	7	20	31	
Total	Panoramic	342	213	66	143	50	817
	CBCT	42	66	59	295	352	

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is similar to that of Sharan and Madjar, in which the classification criteria was observed by both panoramic and CBCT images. In addition to the type of relationship of the root with the sinus floor, sinus floor topography was also considered [2].

In the current study, according to the results of CBCT, frequency of class 0 was 43%, class 1 was 36%, class 2 was 7%, class 3 was 8%, and class 4 was 5%. Thus, class 0 (no contact between root tip and sinus floor) had the maximum frequency. This study result agrees with Bashizadehfakhar et al. study who reported that class 0 had maximum frequency of 38% followed by class 1 with 28.8% [14]. Results of the current study are in agreement with studies of Kilic et al., Sharan and Madjar, Ariji, and Kwak [1, 2, 13, 15].

In first and second premolar, frequency of class 0 was higher due to greater distance to the sinus floor (65% and 58%), but in first molar (45%) and second molar (46%) frequency of the root in class 1 was higher. Based on these findings, first and second premolars are most likely associated with class 0, whereas first and second molars are most likely associated with class 1. Class 2 was observed in first premolar (21%), class 3 in first molar (13%), and class 4 in second molar (12%). Class 2 was observed in first and second premolars (due to lateral position to the anterior sinus wall) and second molar (due to lateral position to the posterior sinus wall).

Consistent with our study, Bashizadehfakhar et al. also demonstrated that frequency of class 0 in second premolar, class 1, 2, and 4 in second molar was higher than other teeth (first premolar was not included in their study). However, unlike our study, class 2 was mostly found in first molar and class 3 in second molar [14]. Similar observation was reported by Ariji et al. as protrusion of root into the sinus was found to be higher in molars compared to premolars [15]. However, in another study by Kwak et al., unlike our findings, class 0 (no contact with sinus) was more common in first and second molars. This difference may be due to different classifications [13].

Therefore, cases in which there is no contact between the root and sinus floor are mostly found in anterior teeth, and cases in which the root protrudes into the sinus are

Table 2. Agreement value between panoramic and CBCT according to Kappa test

	Value	Approx. Sig.
Kappa	0.549	0.000
n	817	

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Table 3. Classification of the relationship between teeth and sinus in panoramic and CBCT imaging

CBCT \ Panoramic	N (%)					
	0	1	2	3	4	Total
0	273(33.5)	57(7)	9(1.1)	3(4)	0(0)	342(42)
1	52(6.4)	148(19.2)	2(2)	9(1.1)	2(2)	213(26.2)
2	18(2.2)	5(0.6)	43(5.3)	0(0)	0(0)	66(8.1)
3	9(1.1)	74(9.1)	5(0.6)	54(6.6)	1(0.1)	143(17.6)
4	0(0)	11(1.4)	0(0)	0(0)	42(5.14)	53(6.54)
Total	352(43.2)	295(36.2)	59(7.2)	66(8.1)	45(5.3)	817(100)

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mostly found in posterior teeth. Thus, the dentists must perform surgeries with more caution in these areas.

To assess the accuracy of panoramic imaging in determining the relationship between posterior teeth roots and sinus floor, the agreement of panoramic and CBCT imaging results was compared. The vertical relationship of the root and sinus was in good agreement (kappa=0.54), which means panoramic method was matched with CBCT method in 557 out of 817 cases. This was similar to the findings of Bashizadehfakhar (55.7%) and Sharan (59%), which compared panoramic and CT methods [2, 14].

Data analysis showed high dependence between CBCT and panoramic imaging results in class 0 (79%). 2D panoramic image, in the presence of distance between sinus floor and teeth roots, provides adequate information to the technician and CBCT prescription is not required.

A total of 213 cases were detected as class one in panoramic method, 148 (69%) cases were confirmed by

Table 4. Comparison of the agreement value between panoramic and CBCT radiographs in root classifications according to chi square test

Comparing Root Classifications in Panoramic and CBCT			
Tooth	N (%)		
	Agreement	Disagreement	Total
4	130	31	161
	80.7	19.3	100
5	73	30	103
	70.9	29.1	100
6	191	112	303
	63	37	100
7	162	88	25
	64.8	35.2	100
8	556	261	817
	68.1	31.9	100

P<0.001

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Table 5. Mean distance between posterior teeth roots and maxillary sinus floor according to Paired T test

Panoramic		CBCT		Difference	
Distance Mean (mm)	SD	Distance Mean (mm)	SD	Distance Mean (mm)	SD
1.52	3.85	2.26	4.22	2.92	0.74 Min=-0.94 Max=-0.53

P<0.000

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CBCT, and the rest mostly showed as class 0. These findings are similar to those of Bashizadehfakhar et al., in which panoramic and CBCT were matched in 89.5% cases of class 0 and in 58.5% cases of class 1 [14].

Our study showed an agreement of 65% between the two types in class 2, which implies among 66 class 2 cases detected by panoramic method, 43 cases were confirmed by CBCT, and the rest showed classes 1 or 0. However, our finding is in contrast with that of Bashizadehfakhari et al. In their study, 80% cases in class 2 in CBCT were mistakenly detected as classes 3 or 4 in panoramic method [14]. In class 3, panoramic and CBCT images were matched in only 37% of the cases, indicating 143 roots apparently penetrating into the sinus, only 54 cases were class 3 in CBCT and the rest were in lower classes. This could be due to 2D nature of panoramic images for which they cannot show buccal-palatal dimension of the roots. Roots with buccolingual position to the sinus appeared to be projected into the sinus. Thus in CBCT, it is more likely that the root is not present in the sinus, which facilitates treatment procedure.

In Freisfield et al. study, of 129 class 3 roots in panoramic method, only 37 roots penetrated into the sinus in CT [12]. However, in another study by Bouquet et al., of 30 third molars projected into the sinus in panoramic image, 23 teeth showed such relationship in CT, which can be due to the type of teeth studied [16]. Similar to our study, Madjar and Sharan's showed a good agreement in class 0 and 1 (86% to 96%) between panoramic and CT images, whereas the agreement was low for class 3 (39%) [2].

In class 4, we found good agreement between panoramic and CBCT methods (79%), whereas the agreement was reported to be 54.5% and 47% in Bashizade-

Table 6. Comparing the agreement of panoramic and CBCT techniques regarding mean distances

Comparison of Mean Distances Between Panoramic and CBCT			
Tooth type	N (%)		
	Agreement	Disagreement	Total
4	110	51	161
	68.3	31.7	100
5	71	32	103
	68.9	31.1	100
6	223	80	303
	73.6	26.4	100
7	200	50	250
	80	20	100
Total	604	213	817
	73.9	26.1	100

P=0.033

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Table 7. Mean distance between root and sinus floor divided by root type and radiography technique

Root Type	No.	Panoramic		CBCT		Difference		P
		Mean Distance (mm)	SD	Mean Distance (mm)	SD	Mean Distance (mm)	SD	
Buccal root First premolar	90	4.71	4.45	5.45	4.94	-0.74	4.02	0.084
Palatal root First premolar	64	4.38	4.55	4.82	4.80	-0.44	4.27	0.40
Root of second premolar	89	2.5	3.53	3.5	4.43	-1.00	3.17	0.004
Mesiobuccal root First molar	98	0.17	3.48	1.38	3.71	-1.21	3.05	0.0001
Distobuccal root First molar	100	0.97	3.77	1.94	4.09	0.97	2.65	0.0001
Palatal root First molar	100	0.74	3.06	1.16	3.44	-0.42	2.26	0.063
Mesiobuccal root Second molar	90	0.0001	2.44	0.94	3.01	0.94	2.28	0.0001
Distobuccal root Second molar	62	0.24	2.84	0.25	2.39	-0.008	2.49	0.97
Palatal root Second molar	63	0.60	2.92	1.23	3.28	-0.63	2.42	0.042

Table 8. Mean distance from lingual and buccal cortical bone divided by root type

Root Type	Cortical Plate	No.	Mean (mm)	SD
Buccal of first premolar	B	90	0.28	0.74
	P	17	0.94	1.29
Palatal of first premolar	B	2	0.001	0.001
	P	17	0.32	0.77
Second premolar	B	85	0.41	0.88
	P	40	1.13	1.28
Mesiobuccal of first molar	B	6	0.001	0.001
	P	97	0.30	0.71
Distobuccal of first molar	B	95	0.28	0.70
Palatal of first molar	B	94	0.95	0.81
	P	3	0.0001	0.001
Mesiobuccal of second molar	B	7	0.64	0.31
	P	89	0.33	0.71
Distobuccal of second molar	B	62	0.60	1.09
Palatal of second molar	B	60	0.65	0.99
	P	3	2.7	3.08

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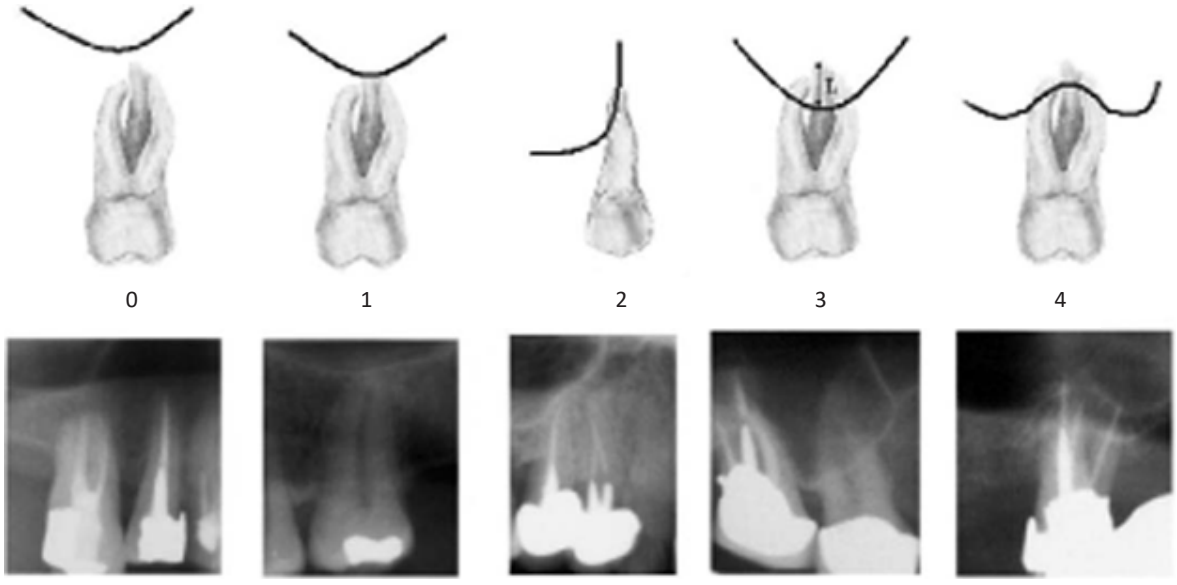

Figure 1. Relation between the roots of posterior maxillary teeth and the maxillary sinus floor in panoramic

hfakhar's and Sharan's studies, respectively [2, 14]. The advantage of this study is detecting class 2 in panoramic images and its good agreement with CBCT method. Since first premolars mostly and second premolar sometimes are in vertical relation with class 0 or 2, panoramic results can be used for premolar areas.

Considering the further distance between sinus and first premolar and the fact that first premolar teeth are mostly in class 0(65%), the agreement of the two imaging methods for the first premolar was 80.7%. Regarding the second premolar, most teeth were in class 0 and a high agreement (70.9%) was observed.

The agreement values with the first and second molars were 63% and 64.8%, respectively, which were significantly lower than premolars. This is due to higher frequency of roots with protrusion and projection (classes 3 and 4) into the sinus and higher number of roots in molar teeth, making the diagnosis more difficult. Panoramic method provides 2D images, and due to lack of clarity in presenting sinus and roots, superimposition of the structures, and lack of buccolingual image of the roots, it cannot show the correct position of the roots into the sinus.

In Shahbazian et al. study, the agreement between panoramic and CBCT methods for the first premolar and canine was similar to our study, which could be due to their

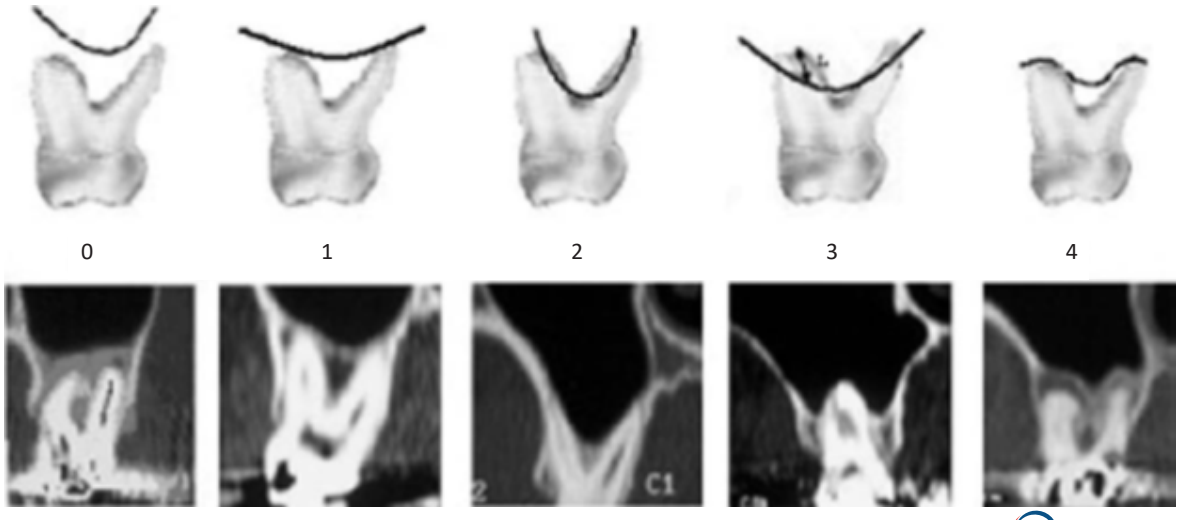

Figure 2. Relation between the roots of posterior maxillary teeth and the maxillary sinus floor in CBCT

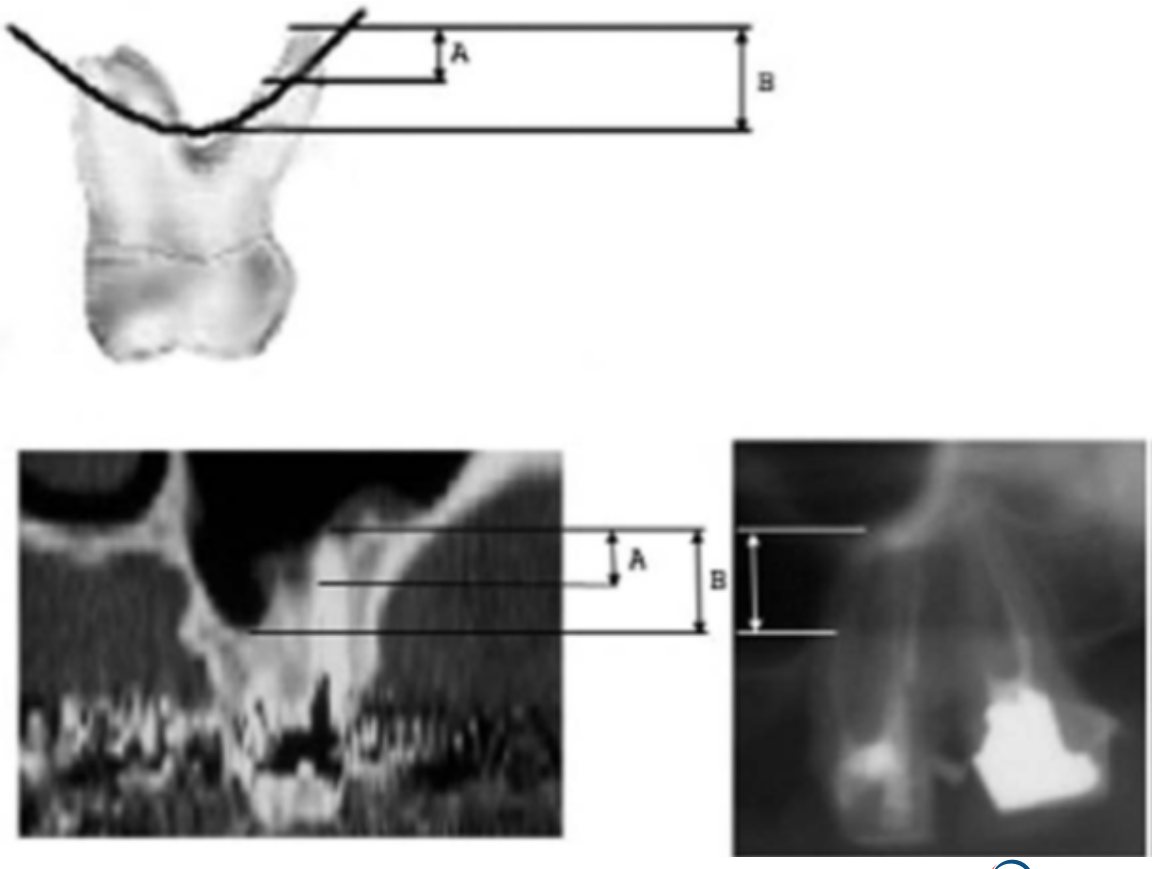

Figure 3. Measurement in CBCT according to longitudinal axis of root teeth

distance from the sinus. However, this agreement was lower in their study compared to ours, which is due to the fact that in their study more than half of the assessed second premolars were in class 2 and there was no good agreement between panoramic and CBCT methods in class 2. Unlike our study, the conformity between the two methods in detecting classes 3 and 4 was high (63% to 83%). This agreement was lower in our study (49% to 62%) [4].

CBCT imaging is able to show precise and detailed view of the protruded roots into the sinus in cross-sectional view, which can present buccolingual dimension of the roots. Parts of the root which are higher than the sinus floor in CBCT images are protruded into the sinus. Our findings confirm this fact. In 86% of the cases with root protrusion into the sinus in CBCT, panoramic imaging showed similar results. This finding is also corroborated by studies of Bashizadehfakhar (94%) and Sharon (91%) [2, 14]. Therefore, when a protrusion of roots into the sinus is observed in posterior areas of the maxilla in panoramic images, CBCT is required to perform surgical-orthodontics procedures and to assess risk of pneumatization to ensure the root is penetrated into the sinus (agreement was only 37%).

The distance between posterior roots of maxillary teeth and sinus was also studied. Our findings show that the distance between maxillary posterior teeth and sinus in panoramic imaging (1.52 mm) was less than that in CBCT (2.26 mm). This result cannot be explained by magnification of 10%-30% of vertical dimensions in panoramic imaging. However, this can indicate lack of accuracy in measuring distances in panoramic imaging, which could be due to low resolution and low clarity of apex and sinus floor. Moreover, statistical results showed that measurements in panoramic method are not similar to that of CBCT method. However, contrary to our finding, Sharan and associates demonstrated that distances in panoramic imaging were 2.1 times higher than in CT [2]. Our results did not show any significant difference between root type and tooth type, which is in agreement with the study of Sharan et al. [2].

In our study, the maximum distance between root and sinus floor was associated with the buccal root of the first premolar (5.45 mm), and minimum distance was associated with the distobuccal root of the second molar (0.25 mm). However, in Kwak study, the maximum distance (6.27 mm) between root and sinus floor was in palatal root of the first premolar and minimum distance (2.74 mm)

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was in distobuccal root of the second molar [13]. Eberhardt stated that the average minimum distance between root and sinus floor for mesiobuccal root of the second molar is 0.83 mm and the average maximum distance for palatal root of the first premolar is 7.05 mm [17]. To know the width of buccal and palatal cortical bone covering the maxillary roots is vital in apical surgeries and implants. Our results are not in line with the findings of Kwak et al. study. In their study, the minimum distance (1.99 mm) between buccal cortical walls to buccal roots was in the first premolar's buccal root and maximum distance (5.48 mm) was in the second molar's mesiobuccal root [13].

5. Conclusion

In summary, we find the exact relationship between maxillary sinus floor and maxillary posterior teeth roots, especially in class 3 panoramic images (projection into the sinus). Therefore, it is recommended to take CBCT images for better assessment and minimizing damage, oroantral communication, and infection.

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Conflict of Interest

The authors declared no conflicts of interest.

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