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Measurements of Posterior Root Apices and Maxillary Sinus Floor according to the Side and Gender Differences using Cone Beam Computerized Tomography

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ABSTRACT

Background: *Understanding the morphological characteristics between the floor of the maxillary sinus and the tips of the maxillary posterior roots is crucial in orthodontics involving diagnosis and treatment planning. The aim of this study was to evaluate the distances from the maxillary posterior root apices to the inferior wall of the maxillary sinus, thickness and density of maxillary sinus floor using cone-beam computed tomography images and the relationships between roots and maxillary sinus according to side, and gender.* ***Materials and methods:*** *Three-dimensional images of each root were checked, and the distances were measured along the true vertical axis from the apex of the root to the sinus floor, and the thickness and density of maxillary sinus floor in 60 patients (30 males, 30 female) aged 18 to 25 years.* ***Results:*** *The results showed that the frequency of root contact with the sinus floor increased from 42.5% at the second premolar to more than 91% at the mesiobuccal roots of the second molars. The more protruded root into the sinus floor was the mesiobuccal root apices of the second molars. The distances of both mesiobuccal and palatal roots of second molars and density of second premolar and first molar in left side were significantly higher than the right side, while the thickness of mesiobuccal roots of the second molar was higher in right side than in left side. The distance and density had no significant difference in both males and females, while the thickness of distobuccal and palatal roots of the second molar is higher in females than in males.* ***Conclusion:*** *In conclusion intrusion of the maxillary molars in small distances between root tips and sinus floor could be difficult and slow due to the pneumatization of the maxillary sinus.*

Keywords: Distance, Thickness, Density of maxillary sinus floor, Cone beam computed tomography

INTRODUCTION

The development of maxillary sinus occurs primarily and is considered as the largest paranasal sinuses. With the beginning of an eruption of the third molars at around 20 years of age, the maxillary sinus growth ends [1,2]. Casually a delicate layer of mucous lining is the only detachment of the roots of teeth from the maxillary sinus [3]. The extension of the adult sinus is different. Hillock, which represents an elevation of the sinus floor or penetration of the roots into the sinus, occurs when the position of inferior sinus walls rests between the roots of the posterior maxillary teeth [4-6]. In orthodontic tooth movement, the distance between the floor of the maxillary sinus and the roots of upper posterior teeth play a very important role in treatment planning [7]. For that reason, understanding the morphological characteristics between the floor of the maxillary sinus and the tips of the maxillary posterior roots is crucial in orthodontics involving diagnosis and treatment planning [8]. Many complications had been resulted from the dispersion of root canal infection into the periapical tissues and contact important anatomical structures [5,9-11]. Also, the errors in operative procedures during endodontic treatment (over instrumentation, overirrigation and overfilling) and massive surgical procedures cause the foreign material to intrude into maxillary sinus [12]. Many studies illustrate the importance of cone beam computerized tomography (CBCT) scans in the recognition of the topography of the maxillary sinus and its correlation with the tips of the maxillary posterior roots [8,13-17]. The alteration of specific modeling that occurs depends on many factors such as craniofacial morphology, age, sex and existence of dental and temporomandibular joint pathology [18]. For instance, the cortical bone of adults is thicker than children and the biting forces are more strong [19]. Also, the sex variance in cortical thickness has found to be

less and maximum bite forces are larger in males [19-21]. The mass of extracellular organic bone matrix whether it is mineralized or not referred to bone density [22]. The main differences between CBCT and conventional computerized tomography (CT) are the shape of the detectors, the kind of beam used, and reconstruction algorithms utilized [23]. Despite the similarity between CBCT and multi-slice computerized tomography (MSCT), the CBCT has less exposure radiation, less cost, in addition to its high spatial resolution [24,25]. The source of X-rays in both conventional CT and CBCT rotate around the patient, gathering data from all directions, which is obtained on a computer and utilized for a 3D image reconstruction. The beam of conventional CT is fan-shaped that creating from a high-output anode generator which spins in spiral form around the patient. This beam after penetrating through the subject is recorded by multi-detectors in a solid-state image which is organized in a 360° array to gather many images slices; afterward, the computer is stacked to create a 3D image [26]. The beam of CBCT is a cone-shaped, that is created from low-energy fixed anode tube, and is penetrated through the patient which is recorded by a connected single silicon 2D panel detector that is either solid-state or amorphous that spin with the beam. Therefore, CBCT scan may gather much more data from the patient in an only one rotation than the conventional CT scan [27].

PATIENTS AND METHODS

This study is composed of CBCT images that have been taken from the Specialized Health Centre in Al-Sadr city, Iraq, in the 3D radiographic department for patients who were attending from December 2017 till May 2018. From the 671 patients that included 436 females and 235 males aged from 5 years to 70 years that was sent for CBCT for the diagnosis of impacted third molars, impacted canine, and for orthodontic purposes, 60 Iraqi samples (30 males and 30 females) ranged between 18-25 years). An informed consent must be made for the subject to be part of the study. All patients were included except with these exclusion criteria which include the history of previous orthodontic treatment, missing posterior teeth (excluding the third molars), pathologic lesions or abnormalities of the maxillary sinus, radiographic signs of periapical disease, medical history (like diabetes, osteoporosis, osteomyelitis). The scanning protocol of CBCT involves kilo voltage: 90, Milli amperage: 10, time of scan: 10.80 seconds, size of voxel: 300. A lateral view of the head, which is called topogram, was achieved that gives the start and end points of the scan, it also confirms that both the vertical axis of the head was perpendicular, and the horizontal axis was parallel to the scan plane, then scan began and persisted for 10.80 seconds, the data was then transferred and stored on the main computer. The obtained images were axial, coronal, and sagittal images together with 3D and panoramic images. After that KODAK dental imaging software was used to reconstruct these images through various types of slicing techniques, which were, orthogonal, curved, custom, and oblique slicing. Positive values were given to the distances that was measured when there was no contact between the root and floor of the sinus (Figure 1), while negative values were given to the distances measured when the side of the root had contact with the sinus floor or the root penetrated into the maxillary sinus locations in MSF, and obtaining the mean of 3 readings that had been appeared on the lower right corner of screen (Figure 2) [6,28-30].

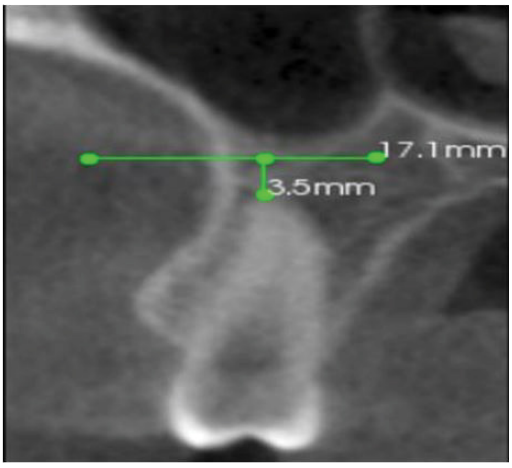

Figure 1 When the root had no contact with the sinus floor, the distance was recorded as a positive value

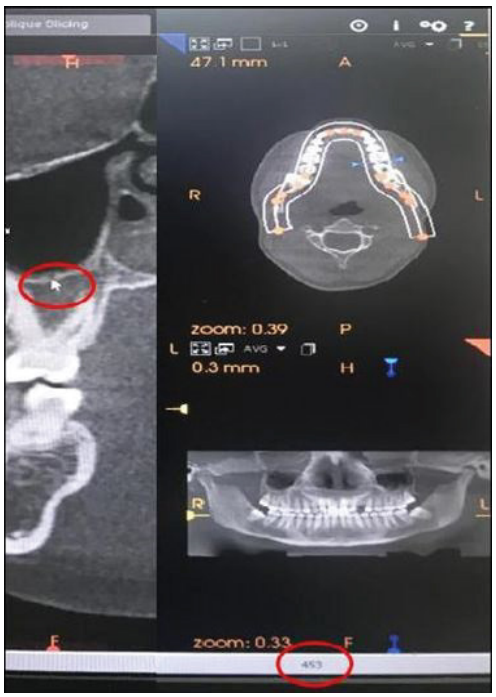

Figure 2 Measurement of density

If the root tip is in contact or penetrates the maxillary sinus, the thickness is equal to 0.00 mm [30]. Measuring maxillary sinus floor (MSF), the cortical bone thickness is in the region closest to the upper posterior root apices and in the furcation areas (Figure 3).

Figure 3 The cortical thickness of the inferior wall of the maxillary sinus

The density of the inferior wall of MSF was measured above the maxillary posterior root apices in both sides. Above the root tip of the second premolar, and above the furcation area for both first and second molars, the density of inferior wall of the sinus was measured by placing the mouse on the third molar.

RESULTS

The sample included 60 subjects (30 males, and 30 females) which were divided into subgroups, Group A has included the right and left sides, Group B was divided into two groups according to the gender.

Descriptive Statistics and Side Difference of the Distance between Floor of Maxillary Sinus and Root Apex of Maxillary Posterior Teeth

Descriptive data of the distances between root apices and the floor of maxillary sinus for the right left and both sides are shown in Table 1. The palatal root of the first molar show the deepest protrusion into the sinus floor on the right side (mean value=-2.592 mm) while the mesiobuccal roots of the second molars show the deepest protrusion into the sinus on the left side (mean value=-3.265 mm) except the second premolar on both sides. The most protruded root in both sides was mesiobuccal of the second molar (mean value=-2.836 mm). Statistical significance was found at the mesiobuccal roots and the palatal root of the second molars.

Table 1 Distances (mm) between root tips and the sinus floor on CBCT according to sides

Roots	Descriptive Statistics						Side Difference		
	Right		Left		Total				
	Mean	S.D.	Mean	S.D.	Mean	S.D.	t-test	d.f.	p-value
5	0.765	4.102	0.847	4.175	0.806	4.121	-0.183	59	0.856
6 MB	-2.182	3.088	-2.333	2.808	-2.258	2.939	0.499	59	0.620
6 DB	-2.498	3.254	-2.747	3.045	-2.623	3.141	0.76	59	0.450
6 P	-2.592	3.334	-3.080	3.107	-2.836	3.219	1.514	59	0.135
7 MB	-2.420	2.732	-3.265	2.478	-2.843	2.631	2.335	59	0.023*
7 DB	-1.683	2.470	-2.185	2.584	-1.934	2.530	1.315	59	0.194
7 P	-0.882	2.497	-1.702	2.492	-1.292	2.518	2.748	59	0.008**
*Significant, **Highly significant									

Descriptive Statistics and Side Difference of the Cortical Bone Thickness

The mean thickness (mm) of the sinus floor above root apices according to sides was calculated. The cortical bone thickness of the inferior wall of MSF nearest to the root apices in both sides ranged from 0.079 mm over the mesiobuccal root of the second molar to 0.978 mm over the furcation area of the first molar as shown in Table 2. The statistical significance was found at the mesiobuccal roots of the second molars with p=0.042.

Table 2 Thickness (mm) of the sinus floor above root apices on CBCT according to sides

Roots	Descriptive statistics									Side difference	
	Right			Left			Total			Wilcoxon Signed Ranks	p-value
	Median	Mean	S.D.	Median	Mean	S.D.	Median	Mean	S.D.		
5	0.750	0.620	0.628	0.800	0.700	0.677	0.800	0.660	0.651	-0.955	0.339
6MB	0.000	0.205	0.469	0.000	0.197	0.425	0.000	0.201	0.446	-0.252	0.801
6DB	0.000	0.168	0.374	0.000	0.105	0.306	0.000	0.137	0.342	-1.201	0.230
6P	0.000	0.132	0.303	0.000	0.102	0.351	0.000	0.117	0.327	-0.980	0.327
6 Furcation	0.900	1.053	0.835	0.900	0.902	0.337	0.900	0.978	0.639	-1.014	0.311
7MB	0.000	0.120	0.342	0.000	0.038	0.208	0.000	0.079	0.285	-2.033	0.042*
7DB	0.000	0.138	0.414	0.000	0.183	0.44	0.000	0.161	0.426	-0.906	0.365
7P	0.000	0.232	0.437	0.000	0.213	0.464	0.000	0.223	0.449	-0.363	0.717
7 Furcation	0.900	0.952	0.281	0.900	0.972	0.331	0.900	0.962	0.306	-0.263	0.792
* Significant											

Descriptive Statistics and Side Difference of the Cortical Bone Density

The mean density of the sinus floor above root apices according to the sides was calculated. The greatest and lowest density of cortical bone found in the left side above the second premolar (mean value=694.833), and second molar roots (mean value=506.917), respectively. The density of the bone was statistically significant at the region above the second premolar, and first molar root tips as in Table 3.

Table 3 Density of the sinus floor above root apices on CBCT according to sides

Roots	Descriptive Statistics						Side Difference		
	Right		Left		Total				
	Mean	S.D.	Mean	S.D.	Mean	S.D.	t-test	d.f.	p-value
5	638.500	133.453	694.833	141.687	666.667	139.941	-2.474	59	0.016*
6	531.717	122.522	568.100	112.804	549.908	118.682	-2.366	59	0.021*
7	533.700	127.897	506.917	131.255	520.308	129.740	1.316	59	0.193
* significant									

Descriptive Statistics and Gender Difference of the Distance between Floor of Maxillary Sinus and Root Apex of Maxillary Posterior Teeth

All mean values of the distance from male subjects were more protruded into the sinus than female, except the second premolar root, which was not protruded. The statistical significance was not found in gender difference as in Table 4.

Table 4 Distances (mm) between the sinus floor and root tips on CBCT according to gender

Roots	Descriptive Statistics				Gender Difference		
	Males		Females				
	Mean	S.D.	Mean	S.D.	t-test	d.f.	p-value
5	0.678	4.239	0.933	4.032	-0.338	118	0.736
6MB	-2.608	2.788	-1.907	3.066	-1.311	118	0.192
6DB	-2.977	3.001	-2.268	3.261	-1.238	118	0.218
6P	-2.970	3.229	-2.702	3.230	-0.455	118	0.650
7MB	-3.065	2.716	-2.620	2.546	-0.926	118	0.356
7DB	-2.338	2.350	-1.530	2.656	-1.766	118	0.080
7P	-1.610	2.272	-0.973	2.723	-1.391	118	0.167

Descriptive Statistics and Gender Difference of the Cortical Bone Thickness

The mean thickness (mm) of the sinus floor above root apices according to gender, the greatest bone thickness in male was found at the furcation area of the first molar root (mean value=1.057), and the lowest thickness seen at the mesiobuccal root of the second molar (mean value=0.067). On the other hand, in the female, the greatest bone thickness found at the furcation area of the second molar root (mean value=0.973), and the lowest thickness was seen at the mesiobuccal root of second molar (mean value=0.092). The statistical significance found at the distobuccal, and the palatal roots of the second molar teeth as shown in Table 5.

Table 5 Thickness (mm) of the sinus floor above root apices on CBCT according to gender

Roots	Descriptive Statistics						Gender difference	
	Males			Females				
	Median	Mean	S.D.	Median	Mean	S.D.	Mann-Whitney U	p-value
5	0.750	0.693	0.683	0.800	0.627	0.622	1727.500	0.692
6MB	0.000	0.152	0.390	0.000	0.250	0.494	1645.500	0.238
6DB	0.000	0.130	0.341	0.000	0.143	0.345	1751.500	0.682
6P	0.000	0.105	0.306	0.000	0.128	0.348	1764.500	0.746
6 Furcation	1.000	1.057	0.838	0.800	0.898	0.329	1551.000	0.188
7MB	0.000	0.067	0.286	0.000	0.092	0.285	1740.00	0.511
7DB	0.000	0.077	0.266	0.000	0.245	0.530	1532.500	0.027*
7P	0.000	0.137	0.384	0.000	0.308	0.494	1454.000	0.014*
7 Furcation	0.900	0.95	0.294	0.900	0.973	0.320	1748.500	0.786
* significant								

Descriptive Statistics and Gender Difference of the Cortical Bone Density

The mean density of the sinus floor above root apices according to gender was calculated. The greatest and lowest bone density was seen in male above the second premolar root (mean value=683.500), and second molar root (mean value=516.967), respectively as in Table 6.

Table 6 Density of the sinus floor above root apices on CBCT according to gender

Roots	Descriptive statistics				Gender difference		
	Males		Females				
	Mean	S.D.	Mean	S.D.	t-test	d.f	p-value
5	683.500	144.453	649.833	134.371	1.322	118	0.189
6	557.400	123.448	542.417	114.262	0.690	118	0.492
7	516.967	138.330	523.650	121.624	-0.281	118	0.779

DISCUSSION

The sample of the study was chosen with no medical history such as (diabetes, osteomyelitis, and osteoporosis), and no dental history such as cysts or no previous orthodontic treatment, periodontal diseases due to the direct effect of these diseases on bone density [31-38]. In contrast to the two-dimensional radiographs, the CBCT supplies accurate images with no distortion and overlapping of the nearby structures of the bone that surrounds the root apices, so that CBCT has been used in diagnosis and treatment planning widely [6,39,40].

Distance

This study showed that the mesiobuccal roots of the second molars had the greatest protrusion into the sinus floor in left sides with an average of -3.265 mm displayed in Table 1. This finding is similar to the results of many previous studies by Eberhardt, Kilic, et al., Georgescu, Pagin, et al., Ok, et al., Kang, et al., and Ahn and Park while in the right side the palatal root of the first molar had the greatest protrusion into the sinus with average (-2.592 mm), which does not agree with other studies that found the distances to the sinus floor shortest for the distobuccal roots of the second molars, followed by the mesiobuccal roots of the second molars [6,8,13,28,41-44]. On the other hand, the root tips of the second premolars and the palatal roots of the second molars were the farthest from the sinus or had the least protrusion into the sinus, and this is consistent with other studies [6,8,13,28,29,42-45]. The left mesiobuccal and palatal root of second molar roots were significantly more protruded into the sinus than the right. Also, Ahn and Park show a significant difference between sides [6]. This was not consistent with other studies that showed no significant difference between sides in Kilic, et al., Von, et al., and Ok, et al., [43]. All roots of the maxillary posterior teeth in the male group were nearest to or more protruded into the sinus than those in the female group. This observation may be explained by the fact that the size of the maxillary sinus on average in males is larger than that in females [46]. This study showed that the mesiobuccal root of the second molar of the male group was the nearest to the sinus or had the greatest protrusion into the sinus (mean value=-3.065 mm), in reverse the second premolar roots of the same group had the farthest distance from the sinus (mean value=0.678 mm) as observed in Table 4. These results agreed with the study of Ahn and Park [6]. While in the female group, the palatal root of the first molar (mean value=-2.702mm) had the greatest protrusion into the sinus floor, and the second premolar had the farthest distance from the sinus (mean value=0.933 mm). These findings were not similar to other studies. Descriptive statistics showed no significant difference found between male and female groups and this result agreed with Kilic, et al., [28]. A contrary view was expressed by the studies of Ok, et al., [43], Von, et al., [45], Kang, et al., [44], and Ahn and Park who show a significant difference between male and female groups [6].

Thickness

The side and gender differences coincide in smallest and greatest thickness of the MSF that had been found over the mesiobuccal root of the second molar, and over the furcation of first molar apex, respectively. This study agreed with Estrela, et al., in which the smallest thickness was found over the second molar apex [30]. In contrast, it disagreed with Estrela, et al., in which the greatest thickness was obtained over the first premolar, and with Yoshmine, et al., both greatest and smallest thickness was obtained [30,47]. Harrison reported that the minimum thickness of the inferior wall of the maxillary sinus was found over the second molar root in 46% of cases which was consistent with the present study [48,49]. In the study of Kwak, et al., the cortical thickness over the distobuccal root of the second molar was the thinnest which differ in side, and gender difference [8]. The reason of the difference between studies due to the thickness over the furcation area of both first and second molars in this study had the greatest values, which resulted from the difference in methodology, number of subjects, and ethnicity. A statistical significance had been

found in second molar roots in side, and gender differences. It is interesting to observe that the area of greatest distance between the root tips of maxillary posterior teeth and the MSF coincided with the area of the greatest thickness near to the apex (second premolars), and the area of lowest distance between the root tips of maxillary posterior teeth and the MSF which coincided with the lowest thickness near to the apex (second molars). This might lead to a higher likelihood of spreading dental infections to the maxillary sinus in the molars area.

Density

The descriptive statistics showed that the density of MSF above the second premolar had the highest value and lowest value observed over the second molar in the side, and gender differences. According to side difference, the greatest density of the floor of maxillary sinus was observed above the root apex of the second premolar on the left side with (mean value=694.833 HU), and on the right side with (mean value=638.500 HU). A significant difference between right and left had been found above the maxillary second premolar, and maxillary first molar, in which the left side had a higher density than the right side. Considering the gender difference, the greatest density of the floor of maxillary sinus was observed above the root apex of the second premolar in a male with (mean value=683.500 HU), and in a female with (mean value=649.833 HU). No statistical significance had been found in density over all the roots. There are no previous studies conducted which measure the density of the MSF, so that, the results of this study cannot be compared with other studies.

CONCLUSION

The more protruded root into the sinus floor was the mesiobuccal root apices of the second molars and the palatal root apices of first molars, and the farthest from the floor of sinus were second premolar root apices. The greatest thickness of the maxillary sinus floor found over the bifurcation area of both first and second molar roots, while the smallest thickness appeared over the mesiobuccal and distobuccal root apices of second molars. The greatest density of maxillary sinus floor found over the second premolar root apices and the smallest appeared over the furcation of second molar root apices. In side difference, the distances of both mesiobuccal and palatal roots of second molar and density of maxillary second premolar and maxillary first molar in left side were significantly higher than the right side. While the thickness of mesiobuccal roots of maxillary second molar was higher in right side than in left side. In gender difference, the distance and density had no significant difference in both male and female, while the thickness of distobuccal and palatal roots of maxillary second molar higher in female than in the male. The intrusion of the maxillary molars in small distances between root tips and sinus floor could be difficult and slow due to the pneumatization of the maxillary sinus.

DECLARATIONS

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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