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Relationship of the maxillary posterior teeth and maxillary sinus floor in different skeletal growth patterns: A cone-beam computed tomographic study of 1600 roots

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ABSTRACT

Purpose: This study evaluated the distance from the posterior root apices to the maxillary sinus floor (MSF) and the frequency of roots touching or protruding through the MSF using cone-beam computed tomography (CBCT).

Materials and Methods: This study included 100 subjects divided into different vertical and anteroposterior skeletal growth patterns. On CBCT images, the distance from the posterior root apices to MSF was measured and the frequency of roots touching or protruding through the MSF was evaluated using NNT software (version 5.3.0.0; ImageWorks, Elmsford, NY, USA).

Results: No statistically significant differences were found in the distance from the posterior root apices to the MSF among vertical skeletal groups ($P>0.05$). The palatal roots of the first molar and the palatal, mesio-buccal and disto-buccal roots of the second molars had significantly less distance from MSF in skeletal class II than in class III ($P<0.05$). The high-angle group had the highest frequencies of roots touching or protruding into the maxillary sinus (49.8%); the lowest proportion of these roots was found in skeletal class III (28.3%) and the highest proportion in class II (50.3%). Males had shorter distances from the posterior root apices to the MSF and higher frequencies of roots protruding through or touching the MSF than females.

Conclusion: Anteroposterior skeletal growth patterns and sex affected the distances from the maxillary posterior roots to the MSF. The frequency of roots protruding into or touching the sinus was affected by both vertical and anteroposterior skeletal groups and sex. These findings have implications for dental practice. ***(Imaging Sci Dent 2022; 52: 19-25)***

KEY WORDS: Maxillary Sinus; Cone-Beam Computed Tomography; Tooth; Cross-Sectional Studies

Introduction

The postnatal growth of the cranium and maxillofacial structures occurs at different speeds at different time periods. The craniofacial structure attains its final shape and structure through combined growth occurring in all 3 planes of space: the vertical, anteroposterior, and transverse planes. Hence, the assessment of the growth patterns of maxillofacial structures also needs to evaluate their growth occurring in all 3 planes. The introduction of cone-beam computed tomography (CBCT) in dentistry has facilitated the straightforward 3-dimensional evaluation of dental and craniofacial structures. Although conventional CT scans could provide 3-dimensional reconstructions, they had relatively high radiation doses and costs. CBCT, in contrast, mitigates these concerns and has high accuracy and sensitivity.[1] CBCT has revolutionized the imaging of craniofacial structures for diagnosis and treatment planning.[2]

The maxillary sinus, also known as Highmore's antrum, is the largest paranasal sinus located in the body of the maxilla.[3] The level of the maxillary sinus floor (MSF) lies at the floor of the nasal cavity by the age of 9 years.[4] If the

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maxillary sinus is large, the MSF can exceed the level of the nasal floor, causing the premolar and molar roots to touch or even protrude into the sinus.[5] The relationship of posterior teeth to the sinus varies according to the size of the maxillary sinus.

The relationship of the maxillary posterior teeth and maxillary sinus has been evaluated in several studies using CBCT.[6-12] However, studies comparing the relationship of the distance from posterior root apices to MSF in different skeletal growth patterns are scarce. Hence, the purpose of this study was to evaluate the distance from the maxillary posterior root apices to the sinus floor and the frequency of roots that touch or protrude into the sinus floor in different skeletal patterns using CBCT.

Materials and Methods

This cross-sectional study included the same sample as the authors' previous study.[13] No subjects received CBCT scans purely for the purposes of this study. The Institutional Review Board of the Third Affiliated Hospital of Sun Yat-sen University reviewed and approved the protocol for this study, and the study was conducted in accordance with the Helsinki Declaration, as amended in 2013. Informed consent was obtained for all the samples included in the study.

The inclusion criteria for the subjects were the availability of a lateral cephalogram, panoramic radiogram, and CBCT and an age of 20 years and above. The CBCT scan was required to show the presence of fully erupted first premolars, second premolars, first molars, and second molars (third molars not required), without any root resorption, peri-apical, and/or peri-radicular lesions. Subjects who had missing or extracted maxillary premolars or molars, a history of orthodontic treatment or orthognathic surgery, or maxillofacial trauma or malformations were excluded from the study.

CBCT images were obtained using a NewTom VG (QR srl, Verona, Italy). The operating parameters were set at 110 kV, 2.3 mA and a scanning time of 3.6 seconds, and the scans were acquired by an experienced radiologist based on the manufacturer's instructions. Patients were asked to bite but not to swallow and not to move their head or tongue while the CBCT scan was being taken. All scans were acquired with the patient sitting upright with the Frankfort horizontal plane parallel to the floor.

In the pre-treatment lateral cephalograms, the sella-nasion to nasion-point A plane angle (SNA), sella-nasion to nasion-point B plane angle (SNB), point A-nasion to nasion-point B plane angle (ANB) and sella-nasion and gonion-gnathion (SN-GoGn) angle were measured using the conventional method; and the subjects were classified into the following skeletal growth patterns. Depending upon the angle formed by the SN-GoGn angle, the subjects were divided into 3 vertical skeletal groups: high-angle (SN-GoGn $>$ 38°), low-angle (SN-GoGn $<$ 26°), and normal-angle (SN-GoGn = 26-38°). Depending upon the ANB angle, the subjects were divided into 3 anteroposterior skeletal groups, as follows: class I (ANB = 1-3°), class II (ANB $>$ 3°), and class III (ANB $<$ 1°).

A sample size of at least 27 patients in each group was determined to be necessary to detect a test power of 95% ($P < 0.05$)[14].

The measurements of the distance from the maxillary posterior root apices to the MSF were performed by NNT software (version 5.3.0.0; ImageWorks, Elmsford, NY, USA) on the CBCT images. The images were magnified by 180% to make a clear radiographic evaluation. All images were aligned on arbitrary long axes of the teeth at the center of their roots; the shortest distances from the center of each radiographic apex or main apical foramen to the MSF were measured for the selected teeth (Fig. 1). For premolars, the distance from the maxillary posterior root apices to the MSF was evaluated for only 1 root, which was close to the MSF. For molars, the distance from the maxillary posterior root apices to the MSF was evaluated for each root (palatal, mesio-buccal, and disto-buccal). The abbreviations used to refer to various tooth roots are given in Table 1. The shortest distance in either sagittal or frontal plane was recorded.[12]

A statistical analysis of the data was performed with SPSS statistical software for Windows (ver. 20, IBM Corp., Armonk, NY, USA). Comparisons between the right and left sides and according to sex were made using the Student

Table 1. Abbreviations of teeth roots measured for distances of the maxillary posterior root apices to the maxillary sinus

Teeth roots	Abbreviations
First premolar	4
Second premolar	5
First molar palatal	6P
First molar mesio-buccal	6MB
First molar disto-buccal	6DB
Second molar palatal	7P
Second molar mesio-buccal	7MB
Second molar disto-buccal	7DB

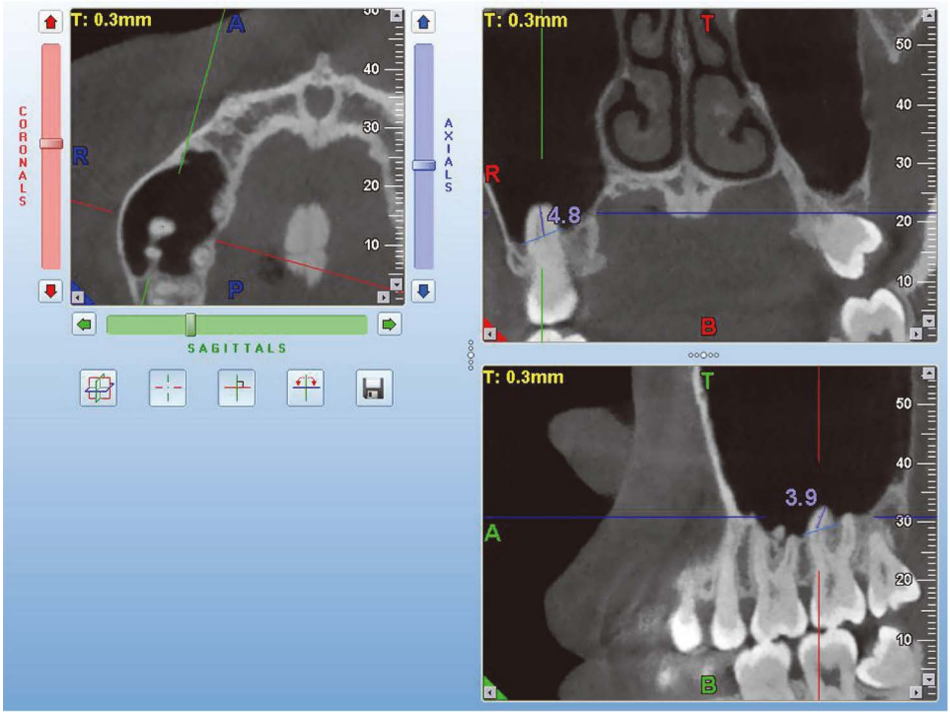

Fig. 1. Measurement of the distances of the maxillary posterior root apices to the maxillary sinus using NNT software.

t-test. The Kolmogorov-Smirnov test showed that the data followed a nonparametric distribution for distance from the maxillary posterior root apices to the MSF. Mean values were compared between the groups using the Kruskal-Wallis test; if significant results were obtained, further pairwise comparisons were made with the Mann-Whitney U test. Correlation analysis was conducted using Spearman correlation coefficients. A *P*-value less than 0.05 was defined as indicating statistical significance.

Results

The intraclass correlation coefficient showed high reliability and reproducibility of the measurements ($r > 0.922$). There were no statistically significant differences in the distance from the maxillary posterior root apices to the MSF between the left and right sides ($P > 0.05$, Table 2). Hence, the distances from the maxillary posterior root apices to the MSF on both sides were pooled to facilitate the determination of central trend measurements. Descriptive statistics of the study groups are presented in Tables 3 and 4. Altogether, 1,600 root apices from 100 subjects (mean age: 26.40 ± 6.77 years; age range: 21-64 years) were evaluated. There were no statistically significant differences in age among the groups ($P > 0.05$). Comparing the different maxillary posterior teeth, 7MB and 7DB had the shortest distances (0.52 ± 3.01 mm and 0.77 ± 3.07 mm respectively)

Table 2. Distances of the maxillary posterior root apices to the maxillary sinus by side (unit: mm)

Roots	Right side (n = 100)	Left side (n = 100)	Total	*P*-value
4	5.48 ± 4.65	5.41 ± 4.49	5.46 ± 4.55	NS
5	2.52 ± 3.93	2.47 ± 4.07	2.51 ± 3.99	NS
6P	1.75 ± 4.16	1.77 ± 3.89	1.78 ± 4.01	NS
6MB	1.73 ± 3.71	1.84 ± 3.68	1.81 ± 3.70	NS
6DB	1.57 ± 3.55	1.65 ± 3.58	1.64 ± 3.57	NS
7P	1.89 ± 3.60	1.92 ± 3.37	1.94 ± 3.52	NS
7MB	0.52 ± 3.01	0.67 ± 2.92	0.63 ± 3.00	NS
7DB	0.77 ± 3.07	0.92 ± 2.96	0.88 ± 3.06	NS

NS: not significant

Table 3. Descriptive analysis of different vertical and anteroposterior skeletal groups

Groups		Number	Male/ Female	Age
Vertical skeletal groups	High-angle	33	16/17	25.03 ± 5.80
	Low-angle	33	17/16	27.24 ± 5.33
	Normal-angle	34	17/17	26.91 ± 8.62
Anteroposterior skeletal groups	Class I	34	15/16	28.39 ± 8.79
	Class II	36	19/17	25.58 ± 5.83
	Class III	33	16/17	25.42 ± 5.15
Total		100	50/50	26.40 ± 6.77

Table 4. Distances of maxillary posterior root apices to the maxillary sinus (unit: mm) in vertical and anteroposterior skeletal groups

Roots	Vertical skeletal group			Anteroposterior skeletal group			Total (n = 100)
	High-angle (n = 33)	Low-angle (n = 33)	Normal-angle (n = 34)	Class I (n = 31)	Class II (n = 36)	Class III (n = 33)	
4	5.21 ± 4.29	4.86 ± 3.41	6.30 ± 5.60	5.34 ± 4.87	5.06 ± 3.56	6.01 ± 5.18	5.46 ± 4.55
5	2.18 ± 3.63	2.00 ± 2.72	3.35 ± 5.12	2.89 ± 4.46	1.79 ± 2.67	2.94 ± 4.62	2.51 ± 3.99
6P	0.90 ± 3.60	1.95 ± 3.18	2.46 ± 4.92	1.94 ± 3.52	0.77 ± 3.08	2.72 ± 5.02*	1.78 ± 4.01
6MB	1.49 ± 3.20	1.66 ± 3.18	2.28 ± 4.52	1.89 ± 3.73	1.16 ± 2.43	2.45 ± 4.63	1.81 ± 3.70
6DB	1.23 ± 3.10	1.78 ± 3.19	1.89 ± 4.29	1.88 ± 3.37	0.86 ± 2.16	2.26 ± 4.71	1.64 ± 3.57
7P	1.56 ± 3.15	2.27 ± 3.25	1.99 ± 4.04	2.28 ± 3.46	1.09 ± 2.32	2.56 ± 4.41*	1.94 ± 3.52
7MB	0.24 ± 2.40	0.95 ± 2.99	0.69 ± 3.49	0.72 ± 2.48	−0.10 ± 1.57	1.35 ± 4.23*	0.63 ± 3.00
7DB	0.57 ± 2.71	1.42 ± 3.24	0.65 ± 3.15	1.08 ± 2.50	0.12 ± 1.81	1.52 ± 4.25*	0.88 ± 3.06

4: first premolar, 5: second premolar, 6: first molar, 7: second molar, P: palatal, MB: mesio-buccal, DB: disto-buccal, *: $P < 0.05$ compared with Class II

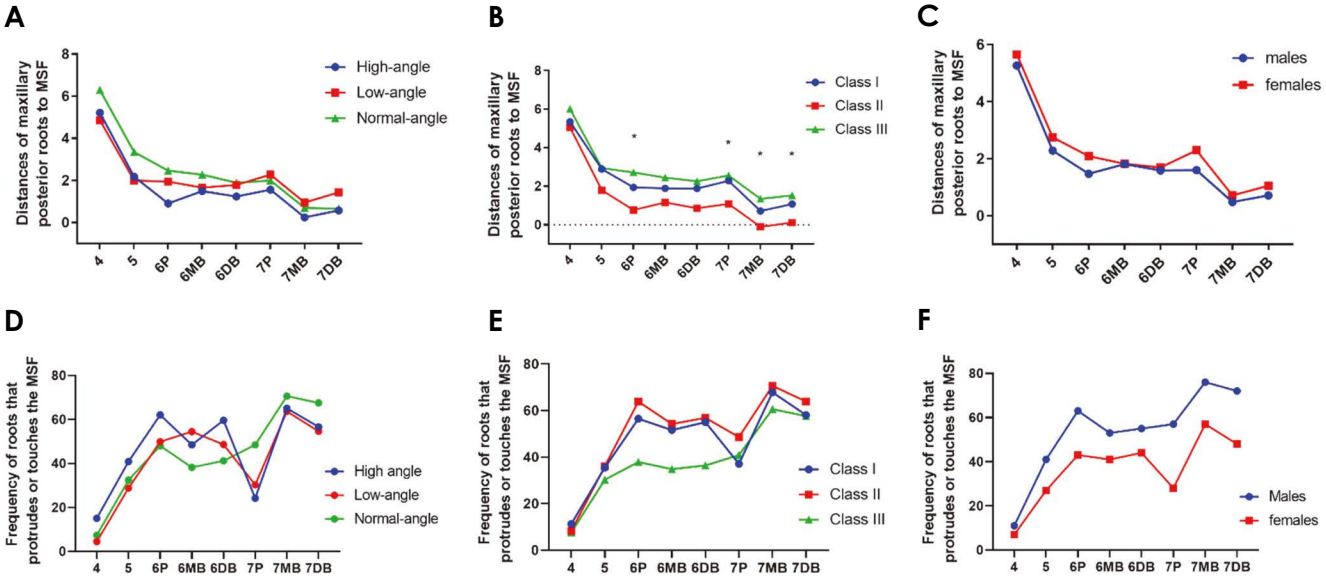

Fig. 2. Graphical diagrams showing the distance from the maxillary posterior root apices to the sinus floor according to the vertical skeletal alignment pattern (A), the anteroposterior skeletal alignment pattern (B), and sex (C), as well as the frequency distribution (%) of roots protruding through or touching the maxillary sinus floor according to the vertical skeletal alignment pattern (D), the anteroposterior skeletal alignment pattern (E), and sex (F) (*: $P < 0.05$).

and the first premolar had the longest distance (5.41 ± 4.65 mm). Among the different vertical skeletal groups, the high-angle group tended to have the shortest distance from the maxillary posterior root apices to the MSF (Fig. 2A); however, there were no statistically significant differences in the distance from the posterior root apices to the MSF among the groups ($P > 0.05$). Among the different anteroposterior skeletal growth groups, 6P, 7P, 7MB, and 7DB in skeletal class II had significantly shorter distances from the posterior root apices to the MSF than those in class III ($P < 0.05$, Fig. 2B).

Men tended to have lesser distances from the posterior root apices to the MSF than women (Table 5, Fig. 2C). However, there were no significant differences in the distance from the maxillary posterior root apices to MSF between men and women ($P < 0.05$).

The frequency of roots that protruded through or touched MSF among the study groups and according to sex is given in Table 6. In general, 7MB and 7DB had the highest frequency (67.2% and 60.1%) of roots that touched or protruded through the MSF. The first premolars were the teeth with the lowest percentage of roots protruding into

or touching the maxillary sinus (9.0%), whereas, 7MB and 7DB had the highest frequencies (60.0-6.5%) of roots protruding into or touching the maxillary sinus. Among the vertical skeletal growth groups, the high-angle group had the highest frequency (49.8%) of roots touching or protruding into the maxillary sinus (Figs. 2D and E). Among the anteroposterior skeletal groups, the skeletal class III group had the least (28.3%) and class II had the highest frequency of roots (50.3%) that touched or protruded through the sinus floor. Similarly, men had a higher frequency of roots protruding into or touching the maxillary sinus than females (men 53.5%, women 36.9%, Fig. 2F).

There was a positive correlation between the distance from the maxillary posterior root apices to the MSF and age for the second premolar and first molar roots ($P<0.05$), as well as for the second molar roots ($P<0.05$).

Table 5. Distances from the maxillary posterior root apices to maxillary sinus floor according to sex (unit: mm)

Tooth	Male	Female	*P*-value
4	5.45±5.12	5.47±3.93	NS
5	2.53±4.54	2.49±3.38	NS
6P	1.67±4.62	1.89±3.30	NS
6MB	2.07±4.28	1.55±2.98	NS
6DB	1.87±4.19	1.40±2.82	NS
7P	1.72±3.97	2.16±3.01	NS
7MB	0.61±3.47	0.65±2.45	NS
7DB	0.89±3.54	0.87±2.49	NS

4: first premolar, 5: second premolar, 6: first molar, 7: second molar, P: palatal, MB: mesio-buccal, DB: disto-buccal, NS: not significant

Discussion

The present study evaluated the distance from the maxillary posterior root apices to the MSF and the frequency of roots that touched or protruded through the MSF in different skeletal growth patterns. A literature search found only a few studies that evaluated the distance from the maxillary posterior root apices to the MSF in different skeletal patterns.[15-18]

Costea et al.[15] evaluated the distance from maxillary posterior root apices to the sinus floor in high-angle, normal-angle, and low-angle skeletal groups in patients aged 7-24 years. The low-angle group had longer distances from the maxillary posterior root apices to the MSF and significantly fewer second molar roots that protruded into the sinus than the normal-angle and high-angle groups. These results are similar to the present findings, and this study also evaluated the distance according to the anteroposterior skeletal growth pattern as well as the frequency of roots touching or protruding through the MSF.

Ahn and Park[16] evaluated distance from the maxillary posterior root apices to the sinus floor and root protrusion into the maxillary sinus in 118 patients divided into different anteroposterior and vertical growth patterns according to the point ANB angle and the Frankfort-mandibular plane angle on lateral cephalograms. The anteroposterior groups had no significant differences in the distance from the maxillary posterior root apices to the sinus floor, whereas the distance from the maxillary posterior root apices to the MSF was shorter and there was more protrusion of the root into the sinus in the high-angle group. The results

Table 6. Frequency of roots that protruded through or touched the maxillary sinus floor (unit: %)

	4	5	6P	6MB	6DB	7P	7MB	7DB	Total
High-angle	15.1	40.9	62.1	48.5	59.6	24.2	65.1	56.6	49.8
Low-angle	4.5	28.8	49.9	54.5	48.6	30.3	63.7	54.6	41.6
Normal-angle	7.4	32.4	47.0	38.2	41.2	48.5	70.6	67.6	44.1
Class I	11.3	35.5	56.5	51.6	55	37.1	67.8	58.1	46.6
Class II	8.3	36.1	63.9	54.2	56.9	48.6	70.6	63.9	50.3
Class III	7.6	30.3	37.9	34.8	36.4	40.9	60.6	57.6	28.3
Male	11.0	41.0	63.0	53.0	55.0	57.0	76.0	72.0	53.5
Female	7.0	27.0	43.0	41.0	44.0	28.0	57.0	48.0	36.9
Right side	8.0	33.0	54.0	48.0	49.0	45.0	71.0	63.0	46.4
Left side	10.0	35.0	52.0	46.0	50.0	40.0	62.0	57.0	44.0
Total	9.0	34.0	53.0	47.0	49.5	42.5	66.5	60.0	45.2

4: first premolar, 5: second premolar, 6: first molar, 7: second molar, P: palatal, MB: mesio-buccal, DB: disto-buccal

of vertical classification were similar to the present findings, but in anteroposterior skeletal class II, 6P, 7P, 7MB, and 7DB showed significantly shorter distances from the maxillary posterior root apices to the sinus floor than in class III. The difference noted might be attributed to the age groups of samples (this study used adults aged ≥ 20 years compared to 10-28 years in the previous study) or may relate to ethnic differences between samples. Similarly, this study divided samples into vertical and anteroposterior skeletal growth patterns using the SN-GoGn angle and ANB angle, respectively.

Kosumari et al.[17] compared the distance from the maxillary posterior root apices to the sinus floor in 30 patients aged 14-28 years divided into skeletal open bite and normal bite groups. Their results showed no between-group differences in the distance from the maxillary posterior root apices to the sinus floor.

Son et al.[18] divided 30 subjects into open bite, normal overbite, and deep bite groups and evaluated the distance from the maxillary posterior root apices to the MSF using CBCT. Their results showed that the open bite group had shorter distances from the maxillary posterior root apices to the MSF than the deep bite group.

The results of this study showed that men tended to have a shorter distance from the maxillary posterior root apices to the sinus floor and a higher frequency of roots touching or protruding through the MSF than women, aligning with previous studies.[19,20] The higher frequency of roots touching or protruding through the MSF in men than in women might mainly be attributed to differences between the sexes in physical growth.

These results have various implications in dentistry. In orthodontics, mesio-distal movement of molars and premolars in maxillary posterior teeth whose root apices protrude into the sinus is delayed, and light forces are recommended for successful space closure as well as intrusion.[21-23] In root canal therapy of the maxillary posterior teeth, especially the mesio-buccal and disto-buccal roots of second molars, special attention is needed not to damage the MSF.

The study samples analyzed in the present study were from patients aged 20 years or above in whom the maxillary sinus had attained its maximum size. The samples were enrolled so that there would be an even mix of male and female subjects. With a test power of 95%, there was no statistically significant difference in age between the groups ($P > 0.05$). The use of pre-orthodontic samples (i.e., not from the general population) may be a limitation of this study. It would have been preferable to use larger samples from the general population. However, it should be noted that lateral cephalograms, panoramic radiograms, and CBCT scans involve radiation exposure and therefore can only be performed if medically indicated.

Different anteroposterior skeletal growth patterns and sex were found to affect the distances from the maxillary posterior roots to the maxillary sinus. The frequency of roots protruding into or touching the sinus was affected by both the vertical and anteroposterior skeletal groups and sex. These findings have several implications in various disciplines of dentistry.

Conflicts of Interest: None

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