

An Analysis of The Relationship between The Maxillary Molars and The maxillary sinus floor in Adult Patient Using Cone-beam Computed Tomography

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Abstract

Background The aim of the study was to evaluate the anatomical relationship between the maxillary molars and the maxillary sinus by using cone beam computed tomography (CBCT). **Methods** A database of maxillary molars were obtained from 91 adult patients by means of images of CBCT. The internal angle, the alveolar bone width, and the distance between root apex and the wall of maxillary sinus were measured by CBCT. The vertical relationship between the maxillary molars and the maxillary sinus were analysed. Vertical relationship of the maxillary sinus was further evaluated. **Results** The value of the internal angle of maxillary third molar is $17.2 \pm 11.5^\circ$. The width of the alveolar bone of third molar is $8.2 \pm 1.7\text{mm}$. Type III, IV and V were the most common relationship in the first and second molars. Type V and I were most frequently observed in the first and second molars. The inner angle of the second molar is larger than that of the first molar. The maxillary first molar had the smallest mean alveolar bone width, and the third molar had the largest average. **Conclusion** This study will provide reference for clinical practice, especially for root canal treatment and tooth implants.

Background

The position of the maxillary posterior teeth region is closely related to that of the maxillary sinus regarding the oral craniofacial anatomy. The close relationship between the maxillary sinus and the roots of the maxillary posterior teeth can lead to accidental oroantral communication. Special care must be taken in treatment planning in the maxillary posterior region.¹ For fear of the potential risk of perforation of the maxillary sinus floor during periapical surgery, this area has been considered as a restricted area for dental implantation.

What is more, it is not unusual that infection of the root canal system may spread through the periapical tissues and reach essential anatomical structures resulting in several complications. The anatomical proximity of the root apices of the maxillary posterior teeth to the maxillary sinus floor may develop inflammatory, infectious or traumatic changes in the maxillary sinus. Figure 0 figure out the relation between these anatomic structures should be considered in order to prevent an iatrogenic procedure and minimize the risks from an infectious disease within the sinus². Even worse, incorrect or unstandard operational process during root canal treatment, such as overinstrumentation, overirrigation and overfilling, can raise the risk of making inroads for foreign materials into the maxillary sinus. Thus, the study of Lavasani SA et al shows an understanding of the maxillary posterior tooth anatomy for apical resection is beneficial to the endodontist³. At the same time, accurate imaging is mandatory for proper planning and implant placement prior to surgery. Although the first modern dental implant was performed in 1952, dental implant placement in the maxilla has not been widely implemented due to close proximity of the maxillary sinus and complications arising from surgery. The assessment of the location of the maxillary molars and premolars, the maxillary sinus, as well as the angulation of the alveolar crest and, in particular, the bone volume, is often a prerequisite for an appropriate planning. Jang JK et al think

understanding the relationship of maxillary posterior teeth with the sinus floor and buccal cortex could provide clinicians valuable information to help reduce iatrogenic damage⁴.

Over the past years, some traditional methods such as X-ray periapical film and curved fault plane have attempted to evaluate the positional relationship between the maxillary posterior teeth and the maxillary sinus, whereas they have unignorable limitations. Imaging problemaxillary sinus such as image overlap and distortion lower the precision of evaluating realistic anatomical positions. To be more precise, periapical radiographs were unable to determine the risk of perforation of the maxillary sinus floor during periapical surgery. Furthermore, because of the complex relationship between the adjacent structures, the exact relationship and measurement between the displayed root and the maxillary sinus is often inaccurate. Thanks to the rise of clinical application of cone beam computed tomography (CBCT), it can serve as an aid in the diagnosis and planning for some obscure dental diseases. It uses a rotating pyramidal shaped X-ray beam with detector in order to reconstruct axial images based on the defined volume by a single rotation. The importance of CBCT scans in the analysis of the morphological characteristics of the maxillary sinus and its relationship with the roots of the maxillary molars has been shown in some studies previously. CBCT has the advantages of undistorted image, high spatial resolution, accurate 3D angle and line lifting measurement. Lan M's team⁵, Ilgüy D et al⁶ and Yoshimine S⁷ figure out for an appropriate approach on dental implant treatment, evaluation of maxillary sinus and maxillary posterior teeth using CBCT can be recommended. In a nutshell, Cone-beam computed tomographic imaging is an effective method to study the position of the posterior teeth roots to the maxillary sinus floor⁸ and it enabled better evaluation of maxillary sinus, posterior teeth and surrounding structures compared to other imaging tools^{9,10,11}. CBCT imaging may assist surgeons to plan grafting and osteotomy procedures, while avoiding neurovascular structures¹².

To date, few studies have combined the alveolar bone width, the internal angle(formed by the long axis of the maxillary premolars and the long axis of the alveolar bone) and the relationship between the maxillary molars and the maxillary sinus to offer valuable information to clinicians. The study of Shokri A's team confirmed that protrusion of teeth roots into the maxillary sinus is more common in male than female¹³. Our study also takes gender into consideration.

Methods

Study sample

A database of 819 maxillary molars from 91 adult patients were obtained by using CBCT. The patients included 24 males (26.37%) and 67 females (73.63%)with a mean age of 25.1 years (range, 18-41 years). Maxillary molars measurements were made on available CBCT images taken for the purpose of dental treatment for the maxillary premolars and molars. All teeth were present without any malformations or bony defects in the maxilla. This study was approved by Tongji University, School of Dentistry. All patients were provided written informed consent before participating in the study. Furthermore, our research was conducted in full accordance with the World Medical Association Declaration of Helsinki.

CBCT Image Acquisition and Analysis

All patients were scanned by CBCT [The 3D Accuitomo CBCT machine (MCT-1(EX-2F); J. Morita Manufacturing Corp., Kyoto, Japan)]. None of the patients had constitutional diseases of the bone or skeletal dysplasia. The acquisition parameters for the CBCT images were 60-100 kV and 1-10 mA. The voxel size in the reconstruction was 0.25 mm. The slice thickness was 0.25 mm and exposure time was 17.5s. The acquisitions were examined with 3-dimensional reconstructions (cross-sectional, axial-sectional and panoramic-sectional) using OneVolumeViewer software (J Morita Corporation, Osaka, Japan). Moreover, the measurements were accomplished on the cross-sectional 3D CT images reconstructed by the medial line of the root crown at the maxillary molars on the axial-sectional 3D CT images and the panoramic-sectional 3D CT images using OneVolumeViewer software in accordance with the method of Yoshimine et al.⁹ (Figure 1). The acquisition process was performed by an experienced radiologist according to the manufacturer's recommended protocol, with the minimum exposure necessary for adequate image quality. A single examiner with education and experience in CBCT measured the distance from the root apex to the inferior wall of the maxillary sinus, the bone width of the alveolar bone in mesial-distal direction, and the internal angle at the maxillary molars and classified the positional relationships between the maxillary teeth and the maxillary sinus into 5 categories on the cross-sectional 3D CT images of CBCT. The bone width of the alveolar bone and the internal angle and the distance from the root apex to the inferior wall of the maxillary sinus were used for statistical analysis.

Measurement of the distance from root apex to the inferior wall of maxillary sinus in the direction of the axis of the tooth and the width of alveolar bone in mesial-distal direction.

The distance from root apex to the inferior wall of

Measurement of the internal angle.

The internal angle (a)⁹

Classification of the positional relationships in the direction of the axis of the tooth between the maxillary molars and the inferior wall of the maxillary sinus on the cross-sectional images.

The vertical relationships in the direction of the axis of the tooth between the maxillary molars and the inferior wall of the maxillary sinus were evaluated and divided into 5 categories (figure 2) according to a revised standard according to the standard stated by the Yoshimine et al.⁹, as follows,

Type I, the inferior wall of maxillary sinus is higher than the buccal root apex and palatal root apex of maxillary molars.

Type II, the inferior wall of the maxillary sinus is below the line formed by buccal root apex and the palatal root apex of the maxillary molars.

Type III, the buccal roots of the maxillary molars have a direct contact with the maxillary sinus inferior wall, and the palatal root apex of the maxillary molars is lower than the maxillary sinus inferior wall.

Type IV, the palatal roots of the maxillary molars have a direct contact with the maxillary sinus inferior wall, and the buccal root apex of the maxillary molars is lower than the maxillary sinus inferior wall.

Type V, both the buccal roots and the palatal roots of the maxillary molars have a direct contact with the maxillary sinus inferior wall.

The distance from each root apex (mesiobuccal root, distal buccal root and palatal root) to the inferior wall of maxillary sinus

The distance from each root apex (mesiobuccal root, distal buccal root and palatal root) to the inferior wall of maxillary sinus in the direction of the axis of the tooth of maxillary molars was measured. Data was concluded as follows,

MBL, the distance from mesiobuccal root apex to the inferior wall of maxillary sinus in the direction of the axis of the tooth.

DBL, the distance from distal buccal root apex to the inferior wall of maxillary sinus in the direction of the axis of the tooth.

PL, the distance from palatal root apex to the inferior wall of maxillary sinus in the direction of the axis of the tooth.

BL, the distance from buccal root apex to the inferior wall of maxillary sinus in the direction of the axis of the tooth in two-rooted tooth.

RL, the distance from root apex to the inferior wall of maxillary sinus in the direction of the axis of the tooth in single-rooted tooth.

Statistical analysis.

The data were evaluated using the SPSS statistical package (SPSS 22.0 for windows, SPSS Inc., Chicago, IL). The linear measurements of the width of the alveolar bone on the maxillary molars, the distance from root apex to the maxillary sinus inferior floor and the angle by categories were averaged and tested for statistical significance using one-way analysis of variance (ANOVA). All tests were performed at a significance level of $P < 0.05$.

Results

About 91 patients (67 females and 24 males) with a mean age of 25.1 years (18-41 years) were assessed. A total of 471 maxillary molars (127 for third molar teeth, 171 for second molar teeth and 173 for first molar teeth) were evaluated.

The mean, standard deviation (SD), minimum (Min.) and maximum (Max.) of the bone width in the mesial-distal direction (W) and the internal angle (α) of each tooth were shown in the Table I. Having completed the process of statistics, the internal angle of maxillary third molar ($17.2 \pm 11.5^\circ$) was obviously bigger than the other two teeth type ($P < 0.01$). The width was larger in third molar ($8.2 \pm 1.7\text{mm}$). It could be easily seen that significant deviations existed between third molar and the other two teeth types. However, no distinct differences could be observed within the first molar teeth type and the second molar teeth type, respectively.

The distributions of the vertical relationships were classified into 5 categories and could be observed in Table II. As was shown in the table. The relation between tooth area and type of mentioned classification was statistically meaningful ($p < 0.001$). Accordingly, as for the vertical relationships, type III, IV and V relationship in which the maxillary sinus inferior wall was lower than the buccal root or palatal root of maxillary molars was most frequently observed with the first and second molars (73.4%, 74.4%). Meantime, the most common type observed in the first and second molars was type V (50.9%, 50.3%) and type I (23.1%, 23.1%), accounting for more than 70 percent of the teeth collectively. Concerning the third molar teeth, the two types (type V and type I) were also most frequently observed, with rather similar percents (38.6% and 39.4%). Overall, type II was the least popular type among all the individual teeth type.

The means and SDs of the measurement of internal angle and bone width by categories on the cross-sectional 3-D CT images of CBCT were illustrated in Table III and Table V. In first molars and second molars, the angle was larger in latter ones. Compared to other types, the internal angle in Type III on the maxillary first molars ($6.2 \pm 4.0^\circ$) was smaller with a great extent. In a sharp contrast, for second molars and third molars, the angle in Type III, which was $14.6 \pm 8.7^\circ$ and $23.1 \pm 8.8^\circ$ respectively, was significantly larger than the other types. For purpose of exploring the correlation between the mean distance and the mean internal angle, we conducted 2-tailed Pearson correlation statistic. As a consequence, there was weak correlation in the first molar teeth type ($r = 0.457$, $p < 0.05$) and third molar teeth type, in type III ($r = -0.400$, $p < 0.1$), meaning that some significant relation could be drawn from these two parameters in type III. Turning to the bone width (mm) in the mesial-distal direction of maxillary molars, no evident differences could be found among the 5 categories in first molars, with a mean width of 7.8mm. Moreover, the bone width in the mesial-distal direction of Type IV was largest on second molars ($8.1 \pm 0.6\text{mm}$) and third molars ($9.1 \pm 1.5\text{mm}$) among all the types.

The distance from each root apex (mesiobuccal root, distal buccal root and palatal root) to the inferior wall of maxillary sinus in the direction of the axis of the tooth of maxillary molars were shown in Figure 3. In general, in two-rooted maxillary second molars and third molars, it was that BL (1.31mm and 0.22mm) was larger than PL (1.83mm and 2.16mm). The distances of each root apex to the maxillary sinus interior wall in three-rooted molars were arranged as follows, $PL > DBL > MBL$. In conclusion, the distance of third molars (0.22mm) was smallest and that of first molars (1.37mm) was largest.

Regarding the mean distance of each apex to the inferior wall of maxillary sinus in the direction of the axis of the tooth, there existed statistically meaningful differences between in gender. To be more precise,

for molar teeth type, longer distance existed between maxillary sinus and root apice of female, especially on second and third molar teeth (1.57mm, 2.31mm). It could be stated that gender was an effective variable in determining the tooth relationship with the maxillary sinus floor. These could offer partial explanation to the fact that in daily dental practices, it is more likely that male patients experience maxillary sinus perforation misdeeds.

Discussion

In summary, this study provides detailed information about the anatomic relationships between maxillary molars and the maxillary sinus floor as well as the internal angle and bone width of each molar teeth using CBCT analysis in Chinese patients. In addition to presenting detailed data about each individual teeth parameters, we also take gender into consideration, wondering if gender index makes a difference. Having been accessed by strict statistics methods, our study comes to some conclusions. Given the statistics, it is vital for clinicians to make accurate evaluations before implanting and extration, especially when dealing with teeth of high potential risk, such as the first molars and the second molars. This study presented a full view of the internal angle of each teeth type, making it more convenient for clinicians to plan corresponding dental treatments precisely.

The proximity of molars to the maxillary sinus floor differed according to tooth type and root numbers. In molar area, the third molar is closest to the maxillary sinus floor and the second molar is closer than the first molar, which presents a potential hazard for clinicians who practice tooth extraction, root canal treatment and so on. Overall, prior knowledge of the position of the root apex relative to the adjacent anatomic structures is beneficial for preoperative treatment planning and the prevention of complications. We come to a same conclusion with Apostolakis D et al that the large variation on the distance of the canal from the sinus floor dictates an individual evaluation of its position and not the use of mean values¹⁴.

Based on previous researches, we compared related parameters by gender difference. The results showed that male had a closer distance from root apex of maxillary molars to the inferior wall of maxillary sinus compared to female. An accepted explanation for this condition has not been figured out, possible reason may be the growth pattern discrepancy in male and female and the fact that roots in male teeth are longer than that in female. It offers some sort of practical sense for dental treatments that gender should be taken into consideration when making preoperative plans.

Former studies have also been conducted for tomography evaluation by adopting cone beam computed tomography. Kang SH et al¹⁵, evaluated the vertical and horizontal relationships between the maxillary sinus floor and the root apices of the maxillary molars with detailed root configuration and the buccal cortical plate. For the vertical relationships, the condition in which a root apex protruded into the maxillary sinus floor, significantly increased toward the posterior (first premolars, 1.5%, second premolars, 14.8%, first molars, 40.5%, second molars, 44.7%, $P < .001$). von Arx T et al conclude only few premolars (and if so second premolars) would present a risk of violating the border of the maxillary sinus during

conventional or surgical endodontic treatment or in case of tooth extraction¹⁶. The apices of the mesiobuccal roots of the second molars had the shortest mean vertical distance to the maxillary sinus floor (0.18 mm) and the thickest mean horizontal distance to the buccal cortical plate (4.99 mm) among buccal roots of 3-rooted molars ($P < .001$). In general, the findings were in accordance with our study, hinting that special care must be taken in treatment planning in the maxillary posterior region. Shokri A et al performed the similar experiment, showing that although most of the teeth did not have contact with the sinus floor, the more posterior the maxillary teeth, the more probability for root protruding into the maxillary sinus. Other than that, it also confirmed that protrusion of teeth roots into the maxillary sinus is more common in male than female, taking gender as an unignorable influence factor¹⁷. Thus, for patients undergoing implantation in maxillary posterior region, CBCT should be performed to determine the height of alveolar crest and anatomy of the maxillary sinus, especially for male patients. Ok E et al adopted the CBCT technology to make a survey of the Turkish population¹⁸. In agreement with former results, the maxillary second molars are closer to the sinus floor when compared with other ones. Also, the second decade and males were most susceptible to undesirable results.

Having realized the importance of understanding the maxillary posterior tooth anatomy for dental treatments, Lavasani SA et al¹⁹ implemented a survey from 505 teeth and respective areas. There came the conclusion that buccal bone was thinnest over the buccal root of the 2-rooted first premolar (0.66 mm) and the mesiobuccal (MB) root of the first molar (0.84 mm) and thickest over the MB root of the second molar (1.91 mm), the palatal bone was thinnest over the palatal root of the maxillary first molar (1.24 mm) and thickest over the single-rooted second premolar (3.26 mm). Having a knowledge of bone thickness over roots and the proximity of each root apex to the maxillary sinus will help the surgeon before and during the surgical procedure. Kosumar W's team in 2017 launched a study to evaluate not only the distances from the maxillary root apices of posterior teeth to the floor of the maxillary sinus (MSDs), but also the distances from the mandibular root apices of the posterior teeth to the mandibular canal (MCDs) in Thai subjects with skeletal open bite and skeletal normal bite. The greatest mean MCDs were from the mesial root apex of the first molars, whereas the least mean MCDs were from the distal root apex of the second molars. What is more, no evident differences in the mean maxillary sinusDs or the mean MCDs between the two groups were discovered²⁰. Meanwhile, several studies applied the CBCT for other purposes. For example, Ilgüy D et al²¹ evaluated the location of the posterior superior alveolar artery (PSAA) and its relationship to the alveolar ridge and maxillary sinus for the awareness that assessment of the maxillary sinus anatomy before sinus augmentation is important for avoiding surgical complications. . Monje A et al examined the sinus lateral wall thickness (LWT) of atrophic posterior maxilla (<10 mm) of patients with complete and partial edentulism and determined the influence of residual ridge height, sex, and age on maxillary LWT. What can be concluded from the research was that the maxillary sinus lateral wall tends to increase in thickness from the second premolar to the second molar and from 5 mm up to 15mm. Additionally, ridge height, presence of teeth adjacent to the edentulous atrophic ridge, and age were shown to influence maxillary sinus LWT²².

Before the application of CBCT has been maturely used, scientists took advantages of other means to evaluate the positional relationship between the molars and maxillary sinus. For the majority of the roots projecting on the sinus cavity in panoramic radiographs, no vertical protrusion into the sinus was observed in CT images. Roots that did protrude into the sinus in the CT showed a protrusion length that was much shorter than the projection length appearance using panoramic radiography. In most cases, particular findings of the maxillary sinus in panoramic imaging may be based on a rather examiner-dependent assessment. Due to the superimposition of different structures, low spatial resolution and visual loss of cortical plates or undulating concavities, precise evaluation of a maxillary sinus finding is difficult in 2D panoramic radiography. Therefore, a comparative reliable conclusion can be attained from a good number of studies that CBCT can better visualize maxillary sinus involvement for posterior teeth than other methods such as panoramic radiography. In details, one study stated that periapical radiography could only spot approximately 40% of apical periodontitis on posterior maxillary teeth and 3% of all apical infections extending to the sinus, seen on CBCT²³.

The benefits of 3D-CT imaging over conventional CT for dental implant treatment are well known. Hence, as the spread of CBCT applications, clinicians should learn to make use of it to make better preoperative treatment plans.

Conclusion

This study demonstrated the anatomical relationships of the interior wall of the maxillary sinus and the morphological characteristics of the alveolar bone on the maxillary molar area using 3D-CT images on CBCT. Our findings have clinically effective applications in dental implant placement and are useful for the reduction of the complications involving the maxillary molar areas.

Abbreviations

CBCT☐cone beam computed tomography

SD, standard deviation; a(The internal angle), the internal angle formed by the long axes of the maxillary molars and alveolar bone.

W, the length of alveolar bone ridge between the mesial and distal cortices at the sites of the maxillary molars.

a,the internal angle

N, number of samples.

SD, standard deviation

Min, The minimum distance from root apex of each tooth to the inferior wall of maxillary sinus in the direction of the axis of the tooth.

a, the internal angle

Declarations

Ethics approval and consent to participate: Ethical approval was given by the Shanghai Clinical Research Ethics Committee..

Consent for publication : All subjects participating in the image acquisition signed the consent form.

Availability of data and material: The datasets used or analysed during the current study are available from the corresponding author on reasonable request..

Competing interest: Not applicable.

Funding: Not applicable.

Authors' contributions: LL and YF conceived and designed the study. LL, YF, HH, and ZL performed the experiments. JG provided the CBCT images. LL and YF wrote the paper. JG, CL, HH and ZL reviewed and edited the manuscript. All authors read and approved the manuscript.

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Tables

Table I. Bone width (W) and angle (a) in the maxillary molars

	First molar		Second molar		Third molar	
	a	W	a	W	a	W
Mean	9.6	7.8	10.5	7.7	17.2*	8.2 [†]
SD	6.6	0.8	7.3	1.2	11.5	1.7
Min	0.6	4.6	0.6	-1.3	1.7	4.0
Max	34.6	10.5	37.6	10.8	52.4	12.0

SD, standard deviation; a(The internal angle), the internal angle formed by the long axes of the maxillary molars and alveolar bone; W(Bone width), the length of alveolar bone ridge between the mesial and distal cortices at the sites of the maxillary molars;*, p < .01; †, p < .01.

Table II. Classifications of the vertical relationship between the root position of the maxillary molars and the maxillary sinus

Type I, The inferior wall of maxillary sinus is higher than the buccal root apex and palatal root apex of maxillary molars; Type II, The inferior wall of the maxillary sinus is below the line formed by buccal root apex and the palatal root apex of the maxillary molars; Type III, The buccal roots of the maxillary molars have a direct contact with the

Classification(n=173)	Type I	Type II	Type III	Type IV	Type V	Total	maxillary sinus inferior wall, and the palatal root apex of the maxillary molars is lower than the maxillary
First molar	Number	40	3	21	21	88	173
	Percentage	23.1%*	1.7%	12.1%	12.1%	50.9%*	100.0%
Second molar	Number	40	2	39	5	87	173
	Percentage	23.1%†	1.2%	22.5%	2.9%	50.3%†	100.0%
Third molar	Number	50	4	18	6	49	127
	Percentage	39.4%‡	3.1%	14.2%	4.7%	38.6%‡	100.0%

sinus inferior wall; Type IV, The palatal roots of the maxillary molars have a direct contact with the maxillary sinus inferior wall, and the buccal root apex of the maxillary molars is lower than the maxillary sinus inferior wall; Type V, Both the buccal roots and the palatal roots of the maxillary molars have a direct contact with the maxillary sinus inferior wall; *, p < .01; †, p < .01; ‡, p < .01;

Table III. Internal angle(a) by type in the maxillary molars(°)

Maxillary molars	Types	I	II	III	IV	V	Total
First molar	Mean	9.3	15.5	6.2*	10.1	10.1	9.6
	N	40	3	21	21	88	173
	SD	5.4	16.6	4.0	5.2	7.2	6.6
Second molar	Mean	9.9	9.2	14.6†	5.6	9.2	10.5
	N	40	1	39	5	86	171
	SD	6.1	.	8.7	5.1	6.5	7.3
Third molar	Mean	17.3	10.7	23.1‡	12.2	16.1	17.2
	N	50	4	18	6	49	127
	SD	13.1	6.1	8.8	13.1	10.2	11.5

N, number of samples; SD, standard deviation; *, p < .01; †, p < .01; ‡, p < .01.

Table IV. The correlation between the mean distance and the mean internal angle in maxillary molars in type III.

	First molars	Second molars	Third molars
Pearson Correlation	0.457*	-.019	-0.400 [†]
Sig. (2-tailed)	0.037	0.677	0.1
N	21	39	18

*, $p < .05$; [†], $p < .1$.

Table V. Bone width (W) in mesial-distal direction by type in the maxillary molars (mm)

Maxillary molars	Types	I	II	III	IV	V	Total
First molar	Mean	8.0	8.2	8.0	7.5	7.8	7.8
	N	40	3	21	21	88	173
	SD	0.8	0.3	0.9	1.2	0.7	0.8
Second molar	Mean	7.9	7.7	7.6	8.1*	7.6	7.7
	N	40	1	39	5	86	171
	SD	1.1	.	0.8	0.6	1.3	1.2
Third molar	Mean	7.6	6.7	8.2	9.1 [†]	8.7	8.2
	N	50	4	18	6	49	127
	SD	1.6	1.3	1.5	1.5	1.6	1.7

N, number of samples; SD, standard deviation; *, $p < .01$; [†], $p < .01$.

Table VI. The distance from root apex of each tooth to the inferior wall of maxillary sinus in the direction of the axis of the tooth of male and female.

		Male		Female	
		Min *	Mean	Min	Mean
First molar	Distance	0.09	1.35	0.42	1.64
	SD	2.69	3.27	3.03	3.41
Second molar	Distance	-0.43	0.88*	0.38	1.57 [†]
	SD	2.02	2.43	3.09	3.43
Third molar	Distance	0.58	1.40 [‡]	1.33	2.31 [§]
	SD	3.17	3.28	3.75	4.00

Min, The minimum distance from root apex of each tooth to the inferior wall of maxillary sinus in the direction of the axis of the tooth; SD, standard deviation; *, p < .01; †, p < .01; ‡, p < .01; §, p < .01.

Figures

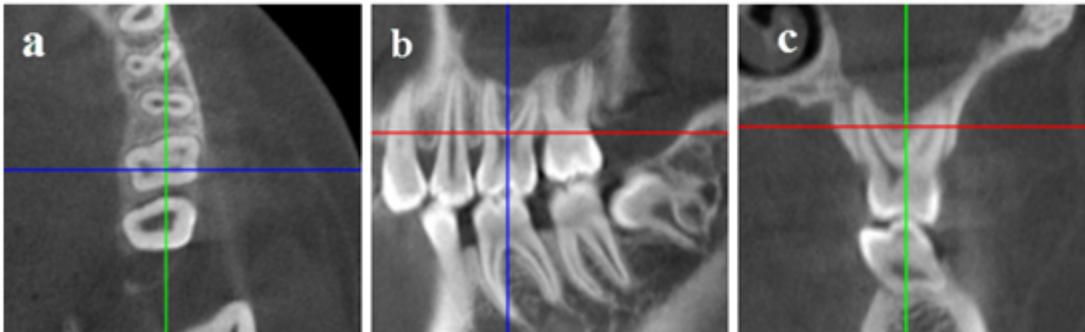


Figure 1

The OneVolumeViewer software shows axial, coronal, and panoramic images at the same time. The cross-sectional CT images (b) were associated with axial-sectional (a) and panoramic-sectional (c) CBCT images using OneVolumeViewer software in accordance with Yoshimine's method⁹. a, Axial-sectional CBCT image that is reconstructed by the referenced line (red line) using OneVolumeViewer software on the roots at the maxillary first molars. b Cross-sectional CT images made by the reconstructed axial-sectional (a) and panoramic-sectional (c) CT Images using OneVolumeViewer software. c, Panoramic-sectional CT images on CBCT reconstructed by the referenced line (blue line) using OneVolumeViewer software on the root crown at the maxillary first molars.

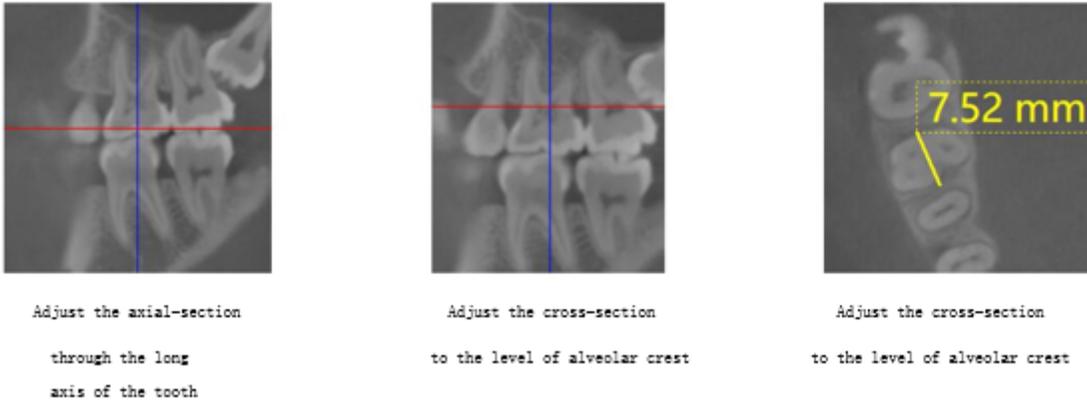


Figure 2

Measurements of the width of aveolar bone.

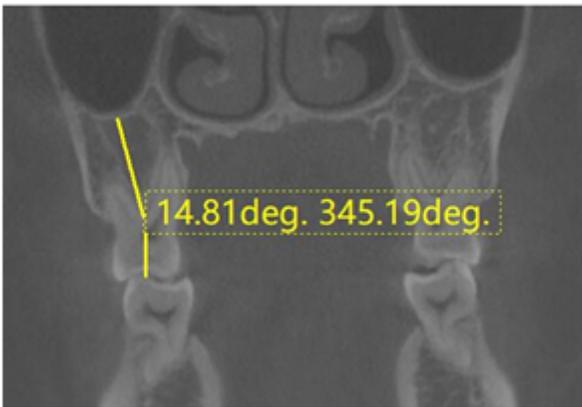


Figure 3

Rotate cross-sectional CT image and panoramic-sectional CT image until the two sections go through the tooth long axis, the internal angle is formed by the long axis of the tooth and the long axis of the aveolar bone. Fisure 3:Measurements of the internal angle.

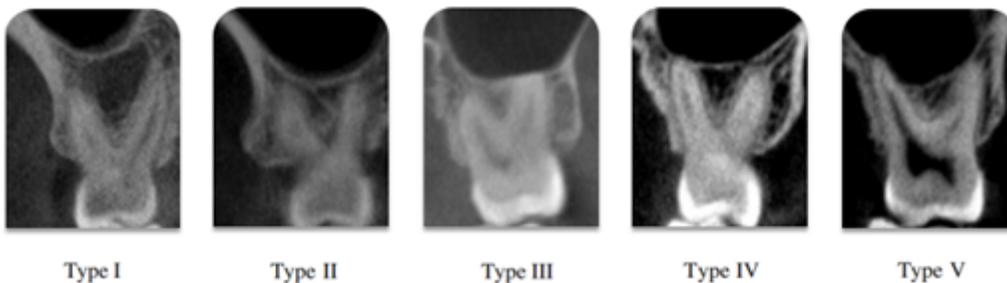


Figure 4

Classification of the vertical relationships in the direction of the axis of the tooth between the maxillary sinus and the roots of the maxillary molars. Type I, The inferior wall maxillary sinus inferior wall is higher

than the buccal root (mesial and buccal) and palatal root of maxillary molars. (left, mesiobuccal root and palatal root, right, distal buccal root and palatal root.) Type II, The inferior wall of the maxillary sinus is below the line between buccal root (mesial or distal) and the palatal root of the maxillary molars. (distal buccal root and palatal root.) Type III, The buccal roots of the maxillary molars have a direct contact with the maxillary sinus inferior wall, and the palatal root apex of the maxillary molars is lower than the maxillary sinus inferior wall. Type IV, The palatal roots of the maxillary molars have a direct contact with the maxillary sinus inferior wall, and the buccal root apex of the maxillary molars is lower than the maxillary sinus inferior wall.(left, mesiobuccal root and palatal root, right, distal buccal root and palatal root.) Type V, Both the buccal root and the palatal root of the maxillary molars have a direct contact with the maxillary sinus inferior wall.(left, mesiobuccal root and palatal root, right, distal buccal root and palatal root.)

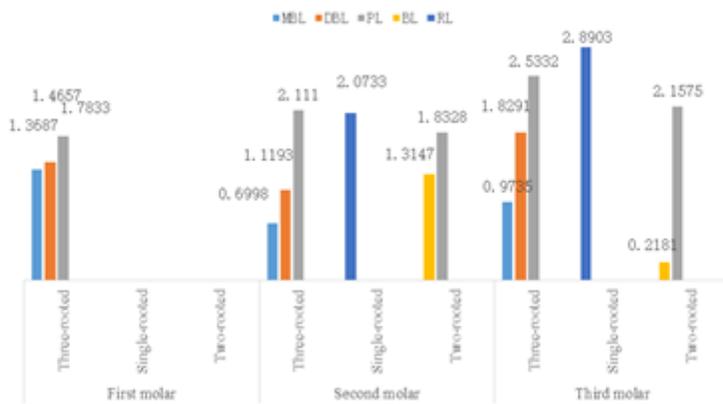


Figure 5

Distance from root apex to the inferior wall of maxillary sinus in the direction of the axis of the tooth(mm).