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ORIGINAL ARTICLE

Evaluation of the Effect of Missing Teeth on Maxillary Sinus Pneumatization using CBCT

Hamid Asadi[1], Azar Eslami Manoochehri[2*], Ehsan Rafiei[3]

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Abstract

Background: One of the influential factors in the reduction of available bone for implant placement is the pneumatization of the maxillary sinus due to the absence of teeth. This study aimed to investigate the effect of edentulism on maxillary sinus pneumatization using cone-beam computed tomography.

Materials and Methods: This cross-sectional, retrospective study examined 114 CBCT images of the maxilla, where one side exhibited at least one edentulous area that had been toothless for a minimum of six months or had a fully healed alveolar ridge, while the other side was dentate. The coronal sections from the edentulous and dentate sides at the second premolar, first molar, or second molar regions were analyzed to assess the depth of the maxillary sinus on each side. Data were analyzed using a paired t-test and one-way ANOVA ($\alpha = 0.05$).

Results: A significant difference was found between the depth of the maxillary sinus in areas with and without teeth ($p < 0.001$). The depth of the maxillary sinus between the regions with and without teeth showed significant differences in the second premolar ($p = 0.01$), first molar ($p = 0.021$), and second molar ($p = 0.046$) regions. Significant differences were observed in the depth of the sinus on the edentulous side compared to the dentate side for both females ($p < 0.001$) and males ($p = 0.024$).

Conclusion: Although tooth loss was statistically associated with increased maxillary sinus pneumatization, the magnitude of this change was minimal and not clinically significant.

Keywords: Pneumatization; Maxillary Sinus; Edentulism; cone-beam computed tomography

Introduction

Dental implants are increasingly used to replace missing teeth due to their high success rate, excellent retention, and aesthetic appeal (1). However, one of the main challenges in placing implants in the posterior maxilla is the presence of the maxillary sinus, the largest paranasal sinus, which lies within the maxillary body. Consequently, its anatomical position can sometimes exacerbate the bone deficiency compared to adjacent areas. Additionally, pneumatization of the maxillary sinus following tooth loss is a significant factor contributing to the reduction in available bone for implant placement (2).

The maxillary sinus begins to develop between the 3rd and 4th months of gestation through the infiltration of the nasal mucosa in the area that will later form the ostium. The sinus volume progressively increases in a process known as maxillary sinus pneumatization. This

Corresponding author: Azar Eslami Manoochehri

Department of Oral & Maxillofacial Radiology, Faculty of Dentistry, Isf.c, Islamic Azad University, Isfahan, Iran
Email: azareslammanoochehri@iau.ac.ir

[1] Faculty of Dentistry, Isf.c, Islamic Azad University, Isfahan, Iran
[2] Department of Oral & Maxillofacial Radiology, Faculty of Dentistry, Isf.c, Islamic Azad University, Isfahan, Iran
[3] Department of Periodontics, Faculty of Dentistry, Isf.c, Islamic Azad University, Isfahan, Iran

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phenomenon continues throughout childhood at an average rate of approximately 2 millimetres per year. It reaches its final volume with the complete eruption of the permanent molars (around 17 to 18 years of age). The greatest increase in sinus volume is observed following the extraction of the second molar (3).

In certain dental treatments, including implant placement and the extraction of upper posterior teeth, it is essential to consider the volume and pneumatization of the maxillary sinus. As the degree of pneumatization of the maxillary sinuses increases, the amount of available bone for certain dental procedures, such as implant placement, decreases. In such cases, procedures such as sinus lift surgery may be required. Understanding the factors influencing the volume and pneumatization of the alveolar bone is essential for minimizing complications associated with inappropriate treatment planning (4).

The increase in sinus volume after tooth extraction significantly reduces the amount of available bone for implant placement (5). This can lead to sinus perforation if dental implants are placed without careful practitioner assessment and consideration. Other complications include root projection into the sinus, oroantral fistula, or root displacement into the sinus following the extraction of the first and second molars, as well as the endo-antral syndrome (the advancement and spread of pulp diseases into the sinus, leading to sinusitis) (3). The topography of the sinus floor and its relationship to implant placement to replace missing maxillary teeth varies depending on factors such as age, size, degree of pneumatization, and tooth position. Therefore, it is essential to obtain radiographic imaging of the patient before starting implant treatment to accurately assess the anatomical conditions and plan the procedure accordingly (6).

Studies conducted on panoramic radiography have reported a significant correlation between tooth loss and maxillary sinus pneumatization (3, 7). However, due to the superimposition of anatomical structures, the results obtained lack sufficient accuracy. CBCT, a more recent imaging method, provides three-dimensional imaging (8, 9) and allows examination of the anatomical regions of the maxillary sinus without superimposition (10).

Multiple studies have investigated the relationship between edentulism and maxillary sinus pneumatization, as well as changes in maxillary sinus volume, and have reported contradictory results (11, 12). Many studies have shown that following tooth loss, the maxillary sinus undergoes pneumatization of the alveolar bone, leading to a reduction in available bone volume. In contrast, Schriber et al (13) argued that the reduction in bone height following edentulism is solely due to alveolar bone resorption, not sinus pneumatization. Additionally, numerous studies have reported a decrease in maxillary sinus volume following tooth loss (11, 12). Some studies have linked this issue more to age rather than the direct effect of edentulism. Consequently, the role of tooth loss in the reshaping of the sinus remains unclear.

Since the relationship between maxillary sinus pneumatization following tooth loss in the posterior maxilla and its consequence, which is the alteration of the lower sinus characteristics, is still not fully understood, and given that this consequence affects the implant treatment plan (13), the present study aimed to investigate the effect of edentulism on maxillary sinus pneumatization using CBCT images.

Materials and Methods

In this cross-sectional and retrospective study, a total of 114 CBCT scans available in the archive of the Oral and Maxillofacial Radiology Department of Islamic Azad University of Isfahan were selected.

The scans were acquired using the Galileos CBCT system (Sirona, Bensheim, Germany) with a peak kilovoltage of 85, a 35-milliamperes-second dose, and a field of view (FOV) of 15 × 15 cm. The selected

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images had to be from the maxilla, with at least one edentulous area on one side and a complete dentition on the other side, and at least 6 months must have passed since tooth extraction at the time of imaging, with the socket completely healed (2).

Images with low quality, images with incomplete volumetric data that did not fully depict both maxillary sinuses, the presence of lesions in the sinus or jawbone under investigation, a history of surgery or implant placement in the area, and the presence of a septum in the maxillary sinus were excluded from the study.

CBCT images were displayed on a 22-inch flat panel LED monitor, LG 22MP57HQ (LG Electronics, Iran, Tehran), with specifications of a resolution of 1920 x 1080, a screen refresh rate of 60 Hz, and (32-bit) True Color. The reconstructed multiplanar images (axial, sagittal, and coronal sections) were evaluated using the OnDemand 3D software.

Initially, the floor of the nasal cavity was aligned parallel to the transverse plane (Figure 1), and then the midsagittal plane of the patient's face was adjusted perpendicular to the transverse plane. The centers of the premolar, first molar, and second molar were selected in the axial section in the absence of teeth on the edentulous side, and the sinus view in the coronal section was examined for each area. The depth of the maxillary sinus was measured from the lowest area of the sinus to the line drawn parallel to the horizontal plane extending along the nasal cavity floor using the software of the device (Figure 2). Coronal images from the edentulous area and the dentate side were selected for examination, with one side considered as the case and the other as the control (2). The site of edentulism was chosen based on the location of the opposing tooth. The evaluations were conducted simultaneously by an expert oral and maxillofacial radiologist and a final-year dental student.

Figure 1. Adjust the nasal floor parallel to the horizontal plane.

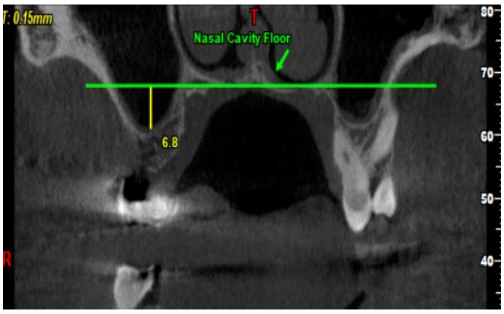

Figure 2. Measurement of Maxillary Sinus Depth

After assessing data normality using the Kolmogorov-Smirnov test, the data were analyzed using a paired t-test and analysis of variance (ANOVA). The tests were performed at an error level of 0.05 using SPSS software, version 26. (IBM Corp., Armonk, NY, USA).

Results

Based on the results of the student's t-test, the mean depth of the maxillary sinus in the edentulous area was significantly increased compared to the dentate area (P < 0.001, Table 1)

Table 1. Comparison of the mean depth of the maxillary sinus between edentulous and dentate areas

Maxillary sinus	n	Mean ± SD (mm)	P value
Edentulous area	114	5.01±3.60	
Dentate area	114	3.94 ±3.43	< 0.001
Mean difference	114	1.07±0.26	

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According to the results of the t-test, the mean depth of the sinus in the second premolar area (P < 0.01), first molar (P = 0.021), and second molar (P = 0.046) in the edentulous area was significantly increased compared to the dentate area (Table 2).

Table 2. Comparison of the mean depth of the maxillary sinus between edentulous and dentate areas at different tooth sites

Variable	Maxillary sinus	n	Mean± SD (mm)	P value
Second premolar	edentulous	30	3.84 ± 3.25	0.01
	dentate	30	2.58 ± 2.39	
First molar	edentulous	48	6.33 ± 3.65	0.021
	dentate	48	5.30 ± 3.63	
Second molar	edentulous	36	4.21 ±3.30	0.046
	dentate	36	3.25 ±3.31	

According to the paired t-test, the mean sinus depth in women (P < 0.001) and in men (P = 0.024) differed significantly between the dentate and edentulous areas (Table 3).

Table 3. Comparison of the mean sinus depth in dentate and edentulous areas by gender

Gender	Maxillary sinus	n	Mean(mm) ± SD	P value
women	edentulous	77	4.69 ±3.28	<0.001
	dentate	77	3.62 ± 3.15	
Men	edentulous	37	5.67 ± 4.16	0.024
	dentate	37	4.60 +3.91	

Discussion

The results of the present study indicated that edentulism significantly affected the depth of the maxillary sinus across all dental regions, including the first premolar, first molar, and second molar, and in both genders. In the study by Cavalcanti et al. (2), the sinus depth on the edentulous side was significantly greater than on the dentate side in the examined patients, suggesting that the maxillary sinuses were pneumatized. As in the present study, the sinus depth in the edentulous area was greater in the molar regions than in other areas. However, in Cavalcanti's study, the overall sinus depth on the edentulous and dentate sides was reported as 6.9 mm and 6 mm, respectively, which was greater than in the present study. This discrepancy may be attributed to the subjects' ethnic background and the methodology employed, as the present study used coronal images for measurement.

In contrast, the aforementioned study used cross-sectional images to assess and measure sinus depth. In Cavalcanti's study(2), the degree of pneumatization prior to tooth extraction influenced the extent of pneumatization after tooth extraction, indicating that greater prior pneumatization was associated with less post-extraction pneumatization, a factor not examined in our study. In the study by Sharan and Madjar (3), the pneumatization of the maxillary sinus following tooth extraction was evaluated using panoramic radiographs, revealing that sinus expansion occurred after tooth extraction in both comparative assessments. The extraction of posterior maxillary teeth resulted in the inferior extension of the sinus

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floor, confirming that pneumatization is a common post-extraction phenomenon. Follow-up panoramic radiographs taken several months later prospectively verified these findings. However, due to patient positioning sensitivity and superimposition of anatomical structures, panoramic imaging presents inherent limitations. Consequently, it is recommended that future investigations employ three-dimensional imaging techniques to provide a more accurate assessment of sinus alterations. Recent evidence supports this approach; Zheng et al. (14) demonstrated that CBCT-based evaluation of maxillary sinus anatomical features, including sinus width, angle, and Schneiderian membrane thickness, offers superior accuracy and clinical relevance in understanding how anatomical variations influence sinus-related surgical and post-extraction outcomes**.** Nevertheless, ethical concerns regarding the justification of repeated CBCT scans before and after tooth extraction limit the feasibility of designing prospective longitudinal studies, which remains a constraint of both the present research and other investigations in this field

In the study by Hettiarachchi et al. (15), no significant differences were found in the expansion of the maxillary sinus in different directions between the two sides. Wu et al. (16) aimed to investigate the relationship between age and the degree of sinus pneumatization and reported that there was no significant difference in sinus depth between the right and left sides. Additionally, there were no significant differences in sinus depth between women and men, and it was noted that with increasing age, the depth of the maxillary sinus significantly decreased. Yamaguchi et al. (12) examined maxillary sinus volume in individuals aged 40 and older using CBCT scans and concluded that edentulism leads to a significant reduction in maxillary sinus volume, contradicting the results of the present study. The differences in methodology and sample size may account for the discrepancies between the two studies. Maxillary sinus floor pneumatization is generally said to occur following maxillary molar extraction (2). It is commonly considered that as teeth are lost, both alveolar resorption and the maxillary sinus pneumatization lead to its expansion (2,6,11). Regarding the effect of tooth loss, in a 3D study, Luz et al. (17) reported no relationship between tooth loss and Maxillary Sinus Volume, as assessed by dentition state (edentulous, partly edentulous, dentate). Moreover, Scriber et al. (13) conducted a similar study and reported that tooth loss had no effect on sinus pneumatization. Conversely, Velasco-Torres et al. (11) found that maxillary sinus volume was smaller in completely and partially edentulous patients than in dentate patients, which they attributed to a lack of stimulation of the maxillary bone. Similarly, Möhlhenrich et al. (18) reported that maxillary sinus volume decreases with increased tooth loss, due to reduced bone stress.

According to the study by Schriber et al. (13), edentulism does not affect sinus dimensions. They examined the volume, area, and largest diameter of the sinus in 50 dentate individuals and 50 edentulous individuals. However, since the samples and controls were not selected from the same individuals, the fully dentate individuals were likely younger. In comparison, the completely edentulous individuals were older; age differences within the study population may have influenced the observed differences. In the study by Bornstein et al. (19), which investigated the volume of the maxillary sinus in dentate and edentulous individuals, it was concluded that age and gender influence maxillary sinus volume, but edentulism status and the side examined do not. The differences in findings from the present study can be attributed to variations in the type of variables and the methods of sample selection.

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Based on the results of the present study, edentulism status is associated with increased maxillary sinus depth; however, the difference between the two variables was only about 1 mm, which may not be clinically significant. It could be argued that the primary cause of the reduction in available bone after tooth extraction is due to the resorption of the alveolar ridge rather than maxillary sinus pneumatization. Nonetheless, to substantiate this claim, the precise timing of tooth loss should also be studied. Given that this study examined only edentulous cases present for over 6 months and lacked sufficient information on the exact timing of tooth loss, a prospective study using three-dimensional scans over multiple, extended time intervals, if feasible, could yield more accurate results in this area.

Conclusion

Tooth loss affects the increase in the depth of the maxillary sinus; however, this amount is likely not clinically significant.

Conflict of Interests: The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial, or non-financial in this article

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