ORIGINAL ARTICLE

Factors Influencing Maxillary Sinus Pneumatization Following Tooth Extraction; A CBCT Based Analysis

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OBJECTIVE: This study aimed at detecting maxillary sinus pneumatization and the associated factors (tooth type, number of missing teeth and sinus floor morphology) after tooth loss in patients reporting to tertiary care hospital.

METHODOLOGY: The Cone Beam Computed Tomography (CBCT) images of posterior maxilla were selected with 1 or more unilateral missing posterior maxillary tooth i.e edentulous site (EdS) and was compared with contralateral dentate site (DS) of the same patient. Variables evaluated with respect to maxillary sinus pneumatization were: sinus height, number of missing teeth, type of missing tooth/teeth and morphology of the sinus floor.

RESULTS: Based on our inclusion criteria, 121 CBCT scans of patients were chosen and were analyzed. The overall maxillary sinus pneumatization (MSP) was 1.69 mm with first molars exhibiting the greatest extent of MSP (1.79±0.84 mm). There were no noteable differences between the genders and age groups. Missing 3 teeth had greater impact on pneumatization (2.74 mm) than missing 2 teeth (2.02 mm) and 1 tooth (1.31mm). Class 4 (superiorly curving sinus floor) had the most pneumatization (1.83 mm) amongst other types of sinus floor morphology.

CONCLUSION: It was found that maxillary sinus pneumatization can occur following tooth loss with the first molars being the most affected. Increased pneumatization was observed with superiorly curving sinus floor and more than one missing adjacent teeth.

KEYWORDS: pneumatization, maxillary sinus, dental implant, sinus morphology, cone beam computed tomography

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INTRODUCTION

The maxillary sinus, despite being present at birth, its size remains minimal until the eruption of the permanent teeth.[1] Its dimensions grow through pneumatization, reaching its final dimensions around the age of 18.

The ongoing physiological process known as sinus pneumatization cause an increase in the paranasal sinuses' volume and size. The pneumatization continues into the zygomatic bone laterally, into the ethmoids posteriorly, and into the hard palate inferomedially through adjacent bony structures. The maxillary sinus's anteromedial wall is the most frequently reported location for pneumatization.[2,3]

According to histological analysis, the stacking of osteoid inferior to the sinus and osteoclastic resorption of the sinus cortical walls induces this pneumatization process. Little is known about the causes of sinus pneumatization. A number of factors influence this process, including genetics, the nasal mucous membrane, growth hormones, craniofacial structure, sinus air pressure, bone density and sinus surgery.[4] Several inflammatory diseases like sinusitis, and environmental factors such as tooth extraction, may also have an impact on the growth of these sinuses. Dental

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implants, jaw surgeries, and other dental procedures including sinus augmentation surgeries depend on the pneumatization of the maxillary sinuses and the residual bone dimensions.[5]

Remodelling on the maxillary sinus floor supports the pneumatization that takes place in the posterior maxilla after tooth extraction. Because of this, the maxillary sinus may only have a paper-thin cortical bone wall at its base and on its lateral borders following loss of teeth, specifically in older individuals.[6,7] Patients with pneumatised sinuses may have challenging anatomical characteristics for intended implant therapy. Consequently, sinus floor elevation (SFE) procedures may be necessary before or simultaneously with dental implant placement. The optimum imaging tool for preoperative examination of the maxillary sinus in conjunction with diagnostic and treatment planning is regarded to be cone beam computed tomography (CBCT).[8]

Numerous investigations into the extent and contributing variables of pneumatization following tooth extraction have produced contradictory findings. Some showed that the sinuses grew larger following tooth extraction, whereas others found no discernible alterations. Furthermore, investigations documenting maxillary sinus pneumatization after tooth extractions have depicted changes in terms of the amount of pneumatization and factors that favour susceptibility. Literature reporting sinus pneumatization showed diversity, with mean values of 0.47±0.23 mm (mean ± standard deviation [SD])[9], 0.9±2.93 mm[10], 2.18±2.89 and 1.83±2.46 mm[11], and 1.30±0.27 mm (mean ± SD).[12] Recently, Lim et al. in 2021 observed maxillary sinus pneumatization at 176 tooth sites with an extent of 1.56±3.93 mm.[13]

Nevertheless, all the above studies mentioned used 2-dimensional method i.e orthopantomogram for pneumatization measurement except for Cavalcanti who used CBCT but didn't assess the associated factors including type of maxillary sinus floor and number of missing teeth.[10]

Another study done by Shriber used customized CBCT software found that no persistent pneumatization was found in the sinus following loss of teeth, and there is no correlation between the maximal dimension (p = 0.0841) of the maxillary sinuses examined and the status of the dentition (dentate/edentulous). Given the aforementioned contradictory findings and the variability of the evaluation instrument, additional research using CBCT is necessary for examining the consequences of posterior dentition extraction in the maxilla.[14]

Since the maxillary sinus is crucial for the positioning of dental implants in the maxillary posterior area, accurate diagnosis and a better understanding of pneumatization at that particular site are necessary for efficient treatment planning. In clinical settings, pneumatization of the maxillary sinus may reduce the amount of available bone that can be used for future implant placement. In order for patients to make an informed decision, they should be informd about the potential outcomes, before or during the tooth extraction.[15]

The aim of this study was to identify maxillary sinus pneumatization and associated factors (tooth type, number of missing teeth and sinus floor morphology) following tooth loss using CBCT in patients reporting to tertiary care hospital.

METHODOLOGY

Approval of this study was taken from the Institutional Review Board (IRB) of the Fatima Memorial College of Dentistry (FMH-04/10/2022-IRB-1098). This cross-sectional study was carried out in the department of Periodontology at Fatima Memorial Dental Hospital Lahore, Pakistan from April 2024 to September 2024.

A sample of size 121 was calculated using 5% level of significance, 95% confidence interval, 80% power of the test and 10% margin of error using the study of Cavalcanti et al.[10] as a reference.

Our inclusion criteria included subjects who were >18 years with completely formed maxillary sinuses and at least 1 posterior maxillary tooth with fully dentate contralateral posterior maxilla. They were prescribed cone beam CT scan as dictated by their treatment plan for dental implant placement and had not undergone CBCT in past 6 months (following ALADA Principle). Both maxillary sinuses must be fully visible in the field of view (FOV).

In contrast, subjects who have previously undergone bone preservation treatments, dental implant placement or have had enlarged adenoids, pathological lesions, sinus infections or sinusitis were not a part of our study. Similarly, maxillary sinuses with complete opacification or more than 4 mm thickening of the Schneiderian membrane were also excluded.

A written consent was taken from all the study participants and demographics was noted. Using non-probability purposive sampling technique, CBCTs of patients fulfilling the selection criteria were included in this study.

The images were split into two sites after being examined bilaterally (one edentulous site versus the contralateral tooth):

a. Edentulous Site (EdS): A tomographic image of the edentulous region

b. Dentate Site (DS): A tomographic image of the contralateral tooth site that corresponds to the edentulous area (second premolar, first molar, or second molar).

Only patients whose teeth were extracted at least six months prior to their presentation were included. Planmeca Romexis 3D CBCT was performed with a 0.2 mm voxel size, a 14-bit greyscale, a 360° rotation, a 16x22 cm field of view, a 120 kV acceleration voltage, a 3 to 7 mA beam current, and a 20-second scan time. Prior to examination, head and maxillary positions were standardised using panoramic and multiplanar reconstructions (coronal, sagittal, and axial). First, the palatal bone was used as a reference to correct the head position of the patient during the sagittal reconstruction. Anterior nasal spine (ANS) and posterior nasal spine (PNS) were joined by a line parallel to the horizontal plane. The horizontal plane and the nasal cavity floor (NCF) were aligned in the coronal reconstruction. The supero-inferior variations in the sinus floor at healed edentate sites were assessed with respect to contralateral dentate sites, using the nasal cavity floor as a reference.

The parameters evaluated on CBCTs were:

a. Sinus height (SH): The linear distance from the maxillary sinus floor's lowest level till the nasal cavity floor. This parameter will be selected as the primary outcome.

b. Maxillary sinus pneumatization (MSP): The difference between the height of the sinuses at the dentate site (DS) and the edentulous site (EdS) (• EdS - DS).

To mitigate bias, the repeatability (intra-observer reliability) of the results was assessed by a single qualified examiner who conducted all dimensional measures twice. Intra-observer reliability was tested on 24 CBCTs and was evaluated using Cohen's kappa statistic, yielding a kappa coefficient of 0.85, which denotes an agreement between repeated assessments. There was a minimum of two weeks between the first and second measurements.

c. Sinus floor morphology: Sharan and Madjar proposed the following classification for the relationship between the root and the sinus floor (class 0: the root not in contact with the lower border of the sinus, class 1: the root in contact with the lower curved border of the sinus floor, class 2: the root positioned laterally outside of the mesial border of the sinus, class 3: the root protruding to the lower curved border of the sinus floor, class 4: the root bordered by the upper curved border of the sinus floor).

STATISTICAL ANALYSIS

The data collected from CBCT was entered in computer program SPSS version 26 for analysis. Categorical variables age, gender, missing tooth, number and type of missing teeth and sinus floor morphology were presented in form of frequency and percentage. For maxillary sinus variables, Kruskal Wallis H-Test and Mann Whitney U-test were performed to compare DS and EdS in relation to primary outcome i.e maxillary sinus pneumatization (MSP). p-value below 0.05 was regarded as statistically significant.

Figure 1: CBCT evaluation of maxillary sinus pneumatization

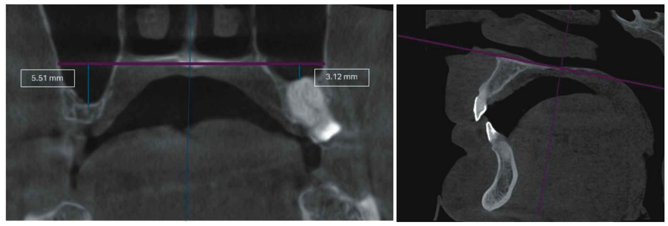


Figure 1a: Nasal cavity floor (NCF) coronal view, aligned with the horizontal plane. **Figure 1b:** Sagittal view of the anterior nasal spine (ANS) to posterior nasal spine (PNS) parallel to the horizontal plane.

RESULTS

Based on our inclusion criteria, 121 CBCT scans of patients were selected and were analyzed. All of these CBCTs were carried out in patients to plan their course of treatment for receiving dental implants. Both maxillary sinuses were completely visible in these CBCT scans.

Table 1: Details of the included patients

		Number (n)	Percentage (%)
Age	18-24 Years	12	9.9
	25-34 Years	9	7.4
	35-44 Years	28	23.1
	45-54 Years	33	27.3
	55-64 Years	25	20.7
	>65 Years	14	11.6
Gender	Male	58	47.9
	Female	63	52.1
Missing Teeth	1	76	62.8
	2	25	20.7
	3	20	16.5
Edentulous site	First Premolar	16	13.2
	Second Premolar	44	36.4
	First Molar	72	59.5
	Second Molar	54	44.6
Sinus Floor Morphology	0	7	5.8
	1	8	6.6
	2	3	2.5
	3	12	9.9
	4	91	75.2

Among the edentulous sites included, there were 16 first premolars, 44 second premolars, 72 first molars, and 54 second molars missing. Single and multiple missing teeth in the posterior maxillary areas excluding third molars were 76 and 45 respectively. The relationship between the root and the sinus floor was classified as class 0 (n=7), class 1 (n=8), class 2 (n=3), class 3 (n=12), and class 4 (n=91). The overall maxillary sinus pneumatization (MSP) was 1.69 mm with sinus height of 3.62 at edentate site and 1.93 at dentate site (Table 1).

No significant differences were found between age groups and MSP (p=0.630). Similarly, there was no significant difference between males and females (p=0.563). In cases where two or more adjacent teeth were missing in the same site, a larger sinus pneumatization was observed than cases in which only one tooth was extracted. Subsequently, results showed a greater amount of MSP (2.74±0.32 mm) when three teeth are missing followed by (2.02±0.46 mm) when two teeth are missing as compared to single missing tooth (1.31±0.71 mm) (Table 2).

Table 2: MSP according to age, gender and missing teeth

		MSP			
		Mean±SD		Median (IQR)	
Age (Years)	18-24	1.65	0.90	1.50	1.09
	25-34	1.66	0.68	2.03	0.89
	35-44	1.93	0.58	1.62	1.26
	45-54	1.54	0.88	1.67	1.64
	55-64	1.60	0.92	2.05	1.16
	>65	1.92	0.70	1.34	1.55
p-value (Kruskal Wallis h-Test)			0.630		
Gender	Female	1.76	0.82	1.70	1.35
	Male	1.63	0.82	1.72	1.25
p-value (Mann Whitney U Test)			0.563		
Missing Teeth	1 Teeth	1.31	0.71	1.18	0.93
	2 Teeth	2.02	0.46	2.03	0.41
	3 Teeth	2.74	0.32	2.83	0.54
p-value (Kruskal Wallis h-Test)			<0.001*		

MSP - mean sinus pneumatization

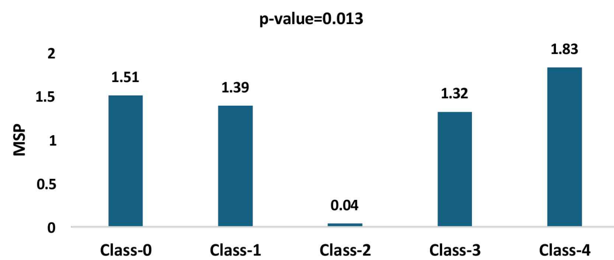
Table 3: Sinus height and MSP according to type of missing teeth

	SHEdS			SHDS			MSP		
	121			121			121		
	Mean±SD		Median (IQR)	Mean±SD		Median (IQR)	Mean±SD		Median (IQR)
First premolar (mm)	3.44	1.07	3.42 (1.94)	1.66	0.55	1.76 (0.77)	1.78	0.85	1.55 (1.11)
Second premolar	3.54	0.93	3.68 (1.01)	2.07	0.79	1.87 (0.87)	1.47	0.76	1.70 (1.24)
First molar	3.62	1.04	3.53	1.85	0.68	1.91	1.79	0.84	1.94
Second molar	3.63	1.25	(1.36) 3.65 (2.29)	1.93	0.70	(1.15) 1.93 (1.12)	1.70	0.78	(1.47) 1.76 (1.16)
First and second premolar	3.24	0.59	2.91 (1.05)	2.11	1	2.09 (1.41)	1.13	0.67	0.96 (0.98)
Second premolar & first molar	3.34	1.13	3.30 (2.60)	1.70	0.58	1.90 (1.19)	1.65	1.01	1.82 (1.51)
First & second molar	3.85	0.94	3.90 (1.55)	2.20	0.88	1.40 (1.41)	1.65	0.72	2.04 (1.14)
Second premolar, first & second molar	3.79	1.17	3.51 (1.98)	2.04	0.79	1.81 (0.67)	1.75	0.94	1.66 (1.38)
Overall	3.62	1.05		1.94	0.73		1.69	0.82	
p-value	0.825			0.660			0.730		

Out of tooth types, first molars showed the highest degree of MSP (1.79±0.84 mm), followed by second premolars (1.78±0.85 mm), second molars (1.70±0.78 mm), and first premolars (1.47±0.76 mm). However, among posterior edentulous area with more than one missing tooth, sites with missing second premolar, first and second molars showed the greater tendency for MSP (1.75±0.94 mm) (Table 3).

In reference to the categorisation of the root-sinus floor relationship, superiorly curving sinus floor showed maximum pneumatization. Thus, the class 4 showed the greatest amount of MSP (1.83±0.75 mm), followed by class 0 (1.51±1.03 mm), class 1 (1.39±0.784 mm), class 3 (1.32±0.80 mm), and class 2 (0.04±0.05 mm) (Figure 2).

Figure 2: Maxillary sinus pneumatization according to the classification of the maxillary sinus floor morphology



Kruskal Wallis h-Test

DISCUSSION

The objective of the present study was to determine maxillary sinus pneumatization and the associated factors using CBCT following tooth loss in patients reporting to a tertiary care hospital. Originally, it was thought that tooth loss can favor sinus pneumatization and the current study's findings further imply that maxillary sinus pneumatization can occur following tooth extraction.

CBCT was utilised in this study to measure differences in sinus floor levels in areas of missing teeth by comparing the dentate and edentate sites within the same patient. The reference lines described by the Cavalcanti et al. were used to evaluate vertical distances on CBCTs.(10) These lines lie in a manner that the nasal cavity floor (NCF) and the horizontal plane lie parallel to each other i.e from the anterior nasal spine (ANS) to posterior nasal spine (PNS), thus allowing for accurate measurements.

In the current study, the average changes in the sinus floor dimensions, which represents maxillary sinus pneumatization was 1.69 mm± 0.82. These results are consistent with earlier researches by Cavalcanti et al. and Sharan et al., which indicated increase in the sinus dimension of 0.9 ± 2.93 mm and 1.83 ± 2.46 mm, respectively.[10,11]

However, Sharan and Majdar employed a different approach using panoramic radiography and took linear measurements to assess changes in the maxillary sinus floor. They discovered that the average sinus pneumatization levels prior to and at least six months following tooth extraction at the same region differed by an average of 1.83 ± 2.46 mm. When their contralateral teeth and the healed edentulous areas were compared, they found a comparable figure of 2.18 ± 2.89 mm. They discovered that the pneumatization was twice as severe. The imaging technology and their incorporation of both single and multiple locations may be responsible for the extent of this disparity. But with single tooth extractions, they only observed 0.54 ± 1.70 mm of pneumatization.(11) A recent investigation by Levi et al. comparing panoramic radiographs taken before and after extraction from a database revealed similar outcomes (1.30 ± 0.27 mm of estimated pneumatization); the group treated with socket preservation also showed less intense pneumatization (0.30 ± 0.10 mm.[12]

Similarly, Ariji and colleagues evaluated the size of the sinuses using standard CT scans, including those of 194 maxillary sinuses in 115 patients whose ages ranged from 4 to 94. Ninety-seven people over the age of twenty were divided into two groups: those with edentulous (61 sinuses) and dentate (133 sinuses). The authors did not find significant changes in the mean volume of the sinuses of both sides compared to the current analysis. Nevertheless, they found that the maxillary sinus volume increased until the child was two years old, after which it decreased.[16] Similar to this, Shriber assessed the maxillary sinus diameters in dentate and edentulous patients using a specially designed customized CBCT software application. He discovered no variations in the size of the sinuses between dentate and edentulous posterior maxillae.[14]

Wagner et al. investigated the effect of residual ridge resorption and sinus pneumatization in residual ridge heights of posterior maxillary region using 400 CT scans. They found that persistent edentulism in the maxillary molar area contributes to mild pneumatization in the sinus walls, even though the depth of the sinus was independent of dentition as the morphological variance.[17]

When each tooth type was assessed separately, our research revealed that the maxillary first molar regions suffer from sinus pneumatization more severely. Sharan also observed that when two or more neighbouring posterior teeth were extracted, as well as when second molars were extracted as opposed to first molars, there was a notable increase in growth, which is consistent with our current findings.[11] Cavalcanti's cross-sectional study, however, revealed that though there were noticeable alterations around second molars but first molars had the highest sinus heights on both sides.[10]

A significant pneumatization was discovered when more than one tooth was missing in the same area (1.75 ± 0.94). The decreased bone resistance to sinus pneumatization in situations where many edentulous areas are next to each other may explain this. By applying functional stresses to the area of the missing tooth, the roots of the adjacent teeth most likely prevent the sinus from growing in situations where only one tooth is missing.[18]

Data analysis based on the topographic relationship between the tooth and the sinus floor shows that teeth with a superiorly curved sinus floor had significantly more pneumatization following extraction (classification 4). According to Waite, this topography happens when the sinus extends between neighbouring teeth, resulting in antral surface elevations.[19]

If a dental implant is planned in these conditions, the clinician should consider ridge preservation or bone grafting at the time of extraction to preserve as much bone height as feasible. These techniques may help preserving thin sinus floor in the extraction site until the socket heals fully by avoiding or lessening pneumatization.[20] It is recommended that more research should be done to see how ridge preservation procedures affect sinus pneumatization. The shortcomings of our study include the absence of pre-extraction documentation, such as radiographs and the exact time duration since the extraction, as well as how much bone is lost during the extraction process. Therefore, we could not assess the effect of duration since extraction on sinus pneumatization.

CONCLUSION

Considering the shortcomings of this study, it was noted that maxillary sinus pneumatization is favoured by tooth loss (multiple adjacent teeth and higher number of teeth) in the posterior maxilla. Furthermore, different tooth types may have different extent of maxillary sinus pneumatization, with first molars being the most affected. Sinus expansion was larger where the anatomy of sinus floor is superiorly curving.

CONFLICT OF INTEREST

None to declare

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