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The Effect of Time Elapsed after Posterior Teeth Extraction on Maxillary Sinus Floor Pneumatization Using CBCT Images

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ABSTRACT

Background and Objective: The posterior maxilla is one of the most challenging areas for implant placement, and sinus pneumatization following the extraction of posterior maxillary teeth is a primary cause of this difficulty. The objective of this study is to evaluate the effect of time elapsed after posterior teeth extraction on maxillary sinus floor pneumatization using Cone Beam Computed Tomography (CBCT) images.

Methods: In this longitudinal quantitative study, data related to all patients who had two CBCT images taken approximately 4 years apart, with at least one posterior tooth extracted between the two CBCT scans, were collected. In total, 39 teeth were examined. In the initial and secondary radiographs, the vertical distance from the line tangent to the nasal floor to the lowest point of the sinus was measured at exactly the same points to assess the degree of pneumatization. These measurements were reported based on the dental region (second premolar, first molar, second molar) and connection or lack of connection to the sinus in the pre-extraction images. Based on the time elapsed after tooth extraction, patients were classified into three categories: less than four months, less than eight months, and more than eight months, and pneumatization changes were compared among them. Intra-observer reliability was calculated by re-scoring the patients after a minimum of 15 days.

Findings: The results showed that after tooth extraction, the degree of pneumatization significantly increased with a mean value of 0.34±0.33 mm ($p<0.001$). The mean level of increase in pneumatization was 0.25 mm over 4 months post-extraction, 0.32 mm over 8 months, and 0.46 mm after more than 8 months. The mean increase in pneumatization was greater in the region of the second molar tooth (0.44±0.41 mm compared to 0.28±0.30 mm, $p=0.660$) and in the region of teeth closer to the sinus (0.38±0.30 mm compared to 0.31±0.36 mm, $p=0.303$); however, these differences were not statistically significant.

Conclusion: Based on the results of this study, post-extraction sinus pneumatization showed a significant difference in the initial months compared to pre-extraction, continuing at a slower rate thereafter. The mean increase was greater in teeth with roots contacting the sinus.

Keywords: *Maxillary Sinus, CBCT, Tooth Extraction, Dental Implant.*

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Introduction

Paranasal sinuses are air-filled cavities located between the skull and facial bones. These sinuses are concentrated around the nasal cavity and have various functions, such as reducing skull weight, humidifying and warming inhaled air, initiating immune defenses, and enhancing voice resonance (1). Additionally, these sinuses act as organs that protect vital structures during facial trauma. Four pairs of sinuses have been identified: maxillary, frontal, sphenoidal, and ethmoidal sinuses (2). The maxillary sinus is the most prominent paranasal sinus and an important component of the midface region, beginning to form in the tenth week of fetal life (3). Its initial form is an oval cavity with smooth walls (2).

Pneumatization is a physiological phenomenon in all paranasal sinuses during growth, leading to an increase in their volume (2, 4, 5). The rate of pneumatization decreases after the sinus growth period ends. Maxillary sinus growth continues until ages 15 to 18 and concludes with the eruption of the third molars at age 20 (6, 7). No clear reason for sinus pneumatization has been proposed other than tooth loss. Numerous studies have reported that sinus pneumatization resumes in adults after tooth extraction (8-12). The maxillary sinus in edentulous adults is significantly larger than in dentate adults (12, 13). The causes of sinus pneumatization are not well understood. Factors influencing this process include heredity, craniofacial configuration, bone density, growth hormones, sinus air pressure, and sinus surgery (14, 15).

Pneumatization of the maxillary sinus floor can create numerous problems in dental treatments. This phenomenon can increase the risk of oroantral fistula formation after tooth extraction (16-19) and pose challenges in endodontic surgery of teeth in the sinus cavity (20, 21). Additionally, it may lead to the entry of foreign bodies, root tips, and teeth into the sinuses during tooth extraction procedures (21) and affect orthodontic tooth movement (22). One of the main issues is implant placement in the posterior maxilla due to bone deficiency (3, 23).

Elsayed et al. examined the length and width of bone in pneumatized areas using 123 CBCT images where a tooth on one side was missing. They concluded that ridge height after tooth extraction in pneumatized areas significantly decreases but is usually sufficient for implant requirements, whereas bone width is greater in edentulous areas (24).

In a study aimed at investigating sinus floor changes by examining CBCT images of 23 patients before and after tooth extraction, Hameed et al. concluded that tooth extraction has only a very slight effect on the position of the maxillary sinus floor (8). In a study comparing sinus dimensions in dentate and edentulous subjects, Schriber et al. (25) reported that the vertical height of the alveolar bone decreases after tooth extraction due to ridge resorption, not pneumatization. Detailed information on the mechanism of pneumatization of the inferior sinus wall is still under discussion. Precise knowledge of this process can help prevent this phenomenon. Few studies have examined the effect of time on maxillary sinus pneumatization in the alveolar bone (5, 9); therefore, the present study was conducted to investigate the effect of time elapsed after posterior teeth extraction on maxillary sinus pneumatization in the alveolar bone using CBCT images.

Methods

This study was approved by the Ethics Committee of Mashhad University of Medical Sciences with code IR.MUMS.DENTISTRY.REC.1397.079. In this longitudinal quantitative study, CBCT images of all patients who visited a private radiology center from 2017 to 2021 were reviewed. Among them, patients who had one posterior maxillary tooth extracted and had images before and after extraction were identified. Patients over 18 years old, with at least half of the sinus visible in the image, extraction of at least one tooth

in the maxillary second premolar and molar areas between the two images, were included. Cases involving extensive surgery in the maxillary sinus or maxilla area, sinus lift surgery, implant placement in the measurement area, use of ridge preservation methods after extraction, craniofacial disorders, or systemic bone-involving diseases such as osteoporosis and diabetes were excluded.

In total, 200 patients had two CBCT images. Among them, tooth extraction in the posterior area occurred between the two images in 31 patients. During this time interval, 25 patients had one tooth extracted, 4 patients had two teeth extracted, and 2 patients had three teeth extracted. Overall, the degree of maxillary sinus pneumatization after extraction of 39 posterior teeth was examined.

CBCT images were taken using a 2013 Mid CBCT imaging unit (Planmeca, Helsinki, Finland). Scanning conditions for most patients were isotropic voxel size of 0.2 mm, tube voltage of 90 kV, tube current of 12 mA, and field of view (FOV) of 10×10 cm. Exposure parameters were adjusted based on patient characteristics and imaging indications.

The images were examined by an oral and maxillofacial radiologist in a room with low to moderate lighting, using Planmeca Romexis Viewer 3/3.0.R software (Planmeca, Helsinki, Finland) on a high-quality 15-inch LED monitor (resolution 1366×768 pixels) (Samsung UNC7000, Seoul, South Korea). The observer was allowed to use magnification tools and adjust image brightness. Intra-observer reliability, by re-scoring samples after at least 15 days, was 0.8 according to Intraclass Correlation (indicating good intra-observer agreement). According to Wood theory, which states that significant changes occur in the alveolar bone four and eight months after tooth extraction (26), patients were classified into 3 groups based on the time elapsed after extraction of the tooth in question: A: Less than four months, B: Less than eight months, C: More than eight months. The following method was used to ensure that exactly the same area and point were examined and measured in the patient's initial and follow-up CBCT images: In the CBCT images, in the sagittal section, the head was oriented so that the line crossing the anterior nasal spine (ANS) and posterior nasal spine (PNS) was parallel to the ground. In the axial section, this line was perpendicular to the coronal plane. Then, a line tangent to the nasal floor was drawn in the coronal section, and the head was oriented so that this line was parallel to the horizontal plane.

To ensure that the coronal sections measured in both the initial and follow-up CBCTs were exactly the same, a straight line corresponding to the coronal section was placed at the mid-root area on the anterior part of the canine tooth canal in the axial section of the initial CBCT images. Then, from this point, we moved toward the tooth of interest or the area where a tooth had previously been extracted, and the exact distance was measured (Figure 1).

Since the sinus floor and alveolar bone crest undergo changes, the nasal floor was used as a fixed, unchanging anatomical reference for measurement. Therefore, the degree of pneumatization was measured as the distance from the line tangent to the nasal floor to the lowest point of the sinus floor (Figure 2). If the sinus floor was positioned above the line tangent to the nasal floor, the values were recorded as negative (10).

The vertical connection of the posterior tooth roots with the maxillary sinus floor before extraction in the initial CBCT images was divided into two categories: the group without sinus connection, where the maxillary sinus floor was right above the root tips, and the group with sinus connection, where the root tips were in contact with the maxillary sinus floor or had penetrated into it. The examined dental areas included the second premolar, first molar, and second molar.

Data were described using statistical tables and charts to show measures of central tendency and dispersion. Data analysis was completed using Shapiro-Wilk, Paired t-test, and Kruskal-Wallis tests. IBM SPSS Statistics v 22.0 was used for statistical analysis, and $p < 0.05$ was considered significant.

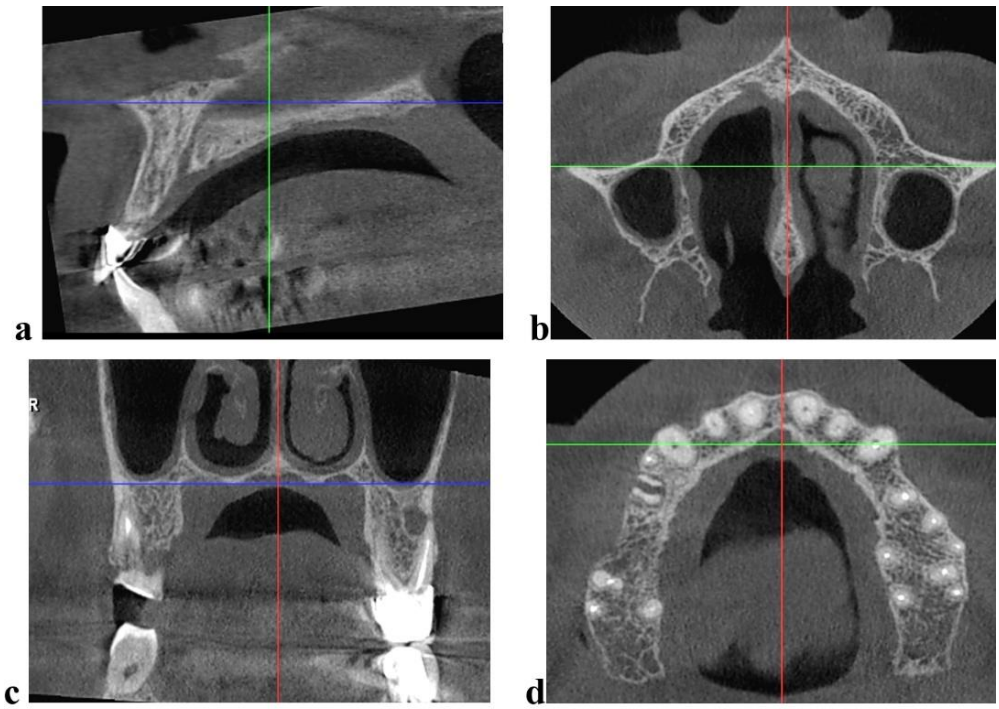


Figure 1. Head positioning. **A) Head adjustment in sagittal section, B) Head adjustment in axial section, C) Head adjustment in coronal section, D) Placing a straight line on the anterior part of the canine tooth canal in the axial section**

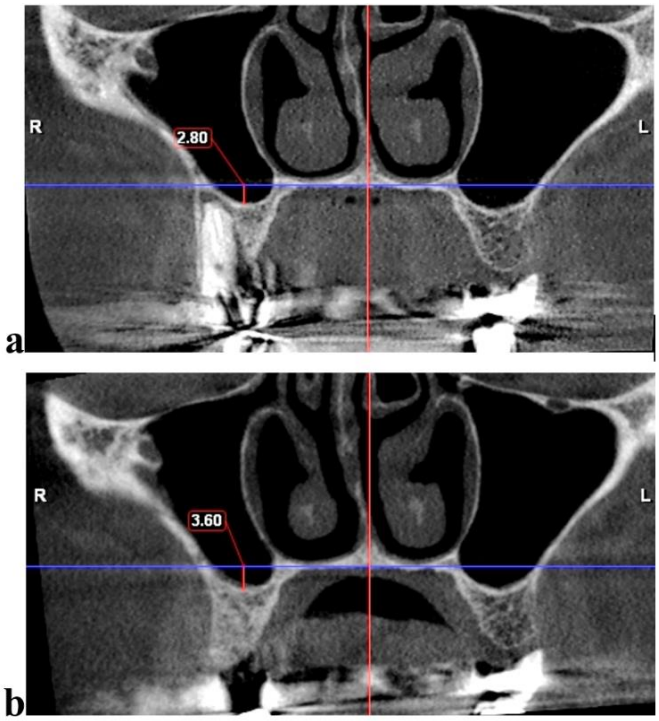


Figure 2. Measurement of pneumatization degree in the first molar of one of the studied patients before and after tooth extraction

Results

The mean age of the studied subjects was 55.38±10.69 years, with a range of 29 to 76 years. 22 teeth from male subjects (56.4%) and 17 teeth from female subjects (43.6%) were examined. The mean time interval between the two imaging sessions was 18.41±12.5 months.

Comparison of pneumatization degree before and after tooth extraction: The change in pneumatization after extraction did not follow a normal distribution, but other variables did. The mean pneumatization before extraction was 2.47±4.05 mm, which increased to 2.81±4.10 mm after extraction, indicating a statistically significant difference ($p<0.001$) (Table 1). No reduction in pneumatization was observed over time in any sample.

Comparison of pneumatization degree after tooth extraction across different time intervals: In samples where less than four months had passed since extraction, the mean change in pneumatization was 0.25±0.27 mm. This value increased with longer post-extraction time, reaching 0.32±0.36 mm in samples under eight months, and 0.46±0.34 mm in those over eight months. No statistically significant difference existed between the three groups. In other words, the greatest increase occurred in the first four months, continuing more slowly thereafter without creating significant differences between groups (Table 2 and Figure 3).

Table 1. Comparison of pneumatization degree before and after tooth extraction

	Number	Mean±SD (mm)	Minimum (mm)	Maximum (mm)	Median	p-value
Before tooth extraction	39	2.47±4.05	-9.80	11.20	2.6	p<0.001*
After tooth extraction	39	2.81±4.10	-9.6	11.8	3.0	p<0.001*

*Indicates statistical significance

Table 2. Comparison of pneumatization extent across the time intervals

Time Interval	Number	Mean±SD (mm)	Min (mm)	Max (mm)	Median	p-value
0-4 months	11	0.25±0.27	0.0	0.8	0.2	0.280
0-8 months	17	0.32±0.36	0.0	1.2	0.2	0.280
>8 months	11	0.46±0.34	0.0	1.0	0.4	0.280

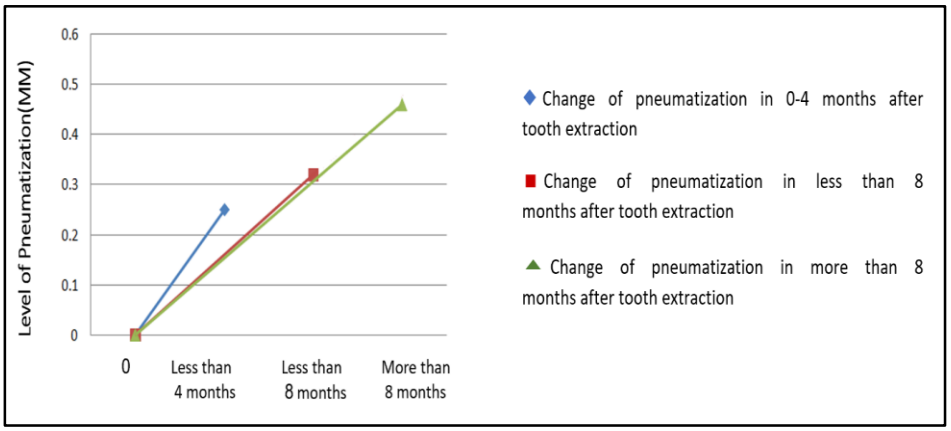


Figure 3. Degree of pneumatization changes across three different time intervals

Comparison of different dental areas: The lowest mean pneumatization increase was for the second premolar (0.28±0.30 mm), and the highest for the second molar (0.44±0.41 mm). Statistically, no significant differences existed between the three maxillary posterior teeth (Table 3).

Comparison of pneumatization based on root proximity to maxillary sinus floor: Mean pneumatization difference was 0.31±0.36 mm for roots not connected to the sinus floor, and 0.38±0.30 mm for connected roots. Although the mean increase was higher in teeth with roots touching the sinus floor, no statistically significant difference existed between the two groups (Table 4).

Table 3. Comparison of pneumatization degree in different dental areas

Tooth	Number	Mean±SD (mm)	Min (mm)	Max (mm)	Median	p-value
2nd Premolar	12	0.28±0.30	0.0	1.0	0.2	0.660
1st Molar	17	0.32±0.31	0.0	1.0	0.2	0.660
2nd Molar	10	0.44±0.41	0.0	1.2	0.4	0.660

Table 4. Pneumatization degree in sinus-connected areas compared to non-connected areas

Group	Number	Mean±SD (mm)	Min (mm)	Max (mm)	Median	p-value
With sinus contact	22	0.31±0.36	0.0	1.2	0.2	0.303
Without sinus contact	17	0.38±0.30	0.0	0.8	0.4	0.303

Discussion

The results of the present study demonstrated that the mean pneumatization significantly increased after tooth extraction compared to pre-extraction. Some studies examining pneumatization after tooth extraction used panoramic images (5, 9), while others used CBCT images similar to our study (8, 23). In a study by Hameed et al. on 23 patients before and after tooth extraction, the mean pneumatization increase was reported as 0.47 mm one year after extraction (8). In a cross-sectional study, Cavalcanti et al. compared sinus pneumatization in CBCT images where a maxillary posterior tooth was missing on one side and present on the other. They concluded that the mean pneumatization increased by 0.9 mm (23). Jung et al. reported a 1.52 mm increase in pneumatization after maxillary molar extraction. Their study compared CBCT images of 59 patients with maxillary posterior teeth on one side and edentulous on the other, measuring pneumatization from the Frankfurt Plane to the sinus floor (11).

The mean pneumatization increase reported by Jung et al. (11) and Cavalcanti et al. (23), who compared sinuses on both sides, was greater compared to our study and Hameed et al. (8), where patients were compared before and after extraction. This difference in results is likely due to differences in methodology and inclusion criteria. Another reason could be comparison of each area with itself after extraction in our study, which minimizes external factors. Al-Haddad reported a mean 2.3 mm increase in pneumatization by comparing the extraction site with the contralateral side in panoramic images (9). Sharan et al. compared panoramic radiographs of 58 patients before and after extraction and stated that the mean pneumatization increase was 1.83 mm (5). In contrast to our study, which focused on pneumatization degree after extraction, Elsayed et al. focused on bone width and height in edentulous vs. dentate areas in pneumatized regions (24).

Greater pneumatization increase in panoramic images may be due to differences in reference points in measurement method, panoramic image magnification, lack of examination of time elapsed after extraction, and incorrect sinus floor observation in panoramic images. Due to the 3D capability of CBCT images, the maxillary sinus floor can be examined more accurately. Additionally, this study used precise, fixed, and reproducible reference points for measuring pneumatization degree. The present study showed that pneumatization rapidly increases during the first four months after extraction. Then, the increase significantly slows down during the next four months. The mean pneumatization increase in patients whose teeth had been extracted for >8 months was 0.46 mm. The mean increase before eight months after extraction was 0.32 mm. This means 70% of pneumatization occurs in the first eight months after extraction, with over three-quarters occurring in the first four months. Since no study has examined pneumatization increase over time, and patient's image has not been compared with their own, less discussion is done in this regard. Hameed et al. reported a mean unilateral post-extraction time of about 1 year (8). Al-Haddad evaluated patients 1–10 years post-extraction and stated that maximum pneumatization occurs within the first year (9). This study aimed to examine sinus pneumatization in early months and shorter intervals for more detail. Since immediate implants are placed in early months after extraction (27), our results can clinically assist surgeons in timing implant treatment to predict early pneumatization increase.

The present study showed the highest mean pneumatization increase in the second molar area and the lowest in the second premolar area; however, there was no statistically significant difference in pneumatization degree between maxillary posterior teeth regions. Similar to our results, Sharan et al. also found the highest pneumatization in the second molar area and stated that extracting more posterior teeth causes greater pneumatization in the molar region (5). However, Cavalcanti et al. stated that the highest pneumatization was in the second premolar area, followed by the second molar (23).

According to Sharan et al., the lowest pneumatization was observed in the group where tooth roots had less sinus contact. The highest pneumatization was in the group where roots had penetrated the sinus (5). Similarly, in our study, greater pneumatization increase was observed in teeth with roots connected to the sinus. However, this was not statistically significant.

Pneumatization increase may be due to air pressure in the maxillary sinus in areas where bone has not yet formed after extraction, as pneumatization decreases after eight months when bone forms.

Although this study reviewed a four-year timeframe for images, examining a longer period or using multiple radiology centers as well as the effects of certain variables like gender could provide greater confidence in results. Future studies using this method are recommended. Additionally, it is recommended to examine the role of the patient's age at the time of tooth extraction on the degree of pneumatization.

This study showed significant sinus pneumatization difference post- vs. pre-extraction in early months, continuing more slowly thereafter. Mean pneumatization increase was higher in teeth with root-sinus contact, but it was not statistically significant.

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