

Dimensional changes of the maxillary sinus following tooth extraction in the posterior maxilla with and without socket preservation

Itay Levi, DMD¹ | Michal Halperin-Sternfeld, DMD, MSc¹  |

Jacob Horwitz, DMD^{1,2} | Hadar Zigdon-Giladi, DMD, PhD^{1,2} | Eli E. Machtei, DMD^{1,2}

¹Department of Periodontology, School of Graduate Dentistry, Rambam Health Care Campus, Haifa, Israel

²Faculty of Medicine, Technion – Israel Institute of Technology, Haifa, Israel

Correspondence

Itay Levi, Department of Periodontology, School of Graduate Dentistry, Rambam Health Care Campus. P.O.B 9602, Haifa 31096, Israel.
Email: itayjlevi@gmail.com

Abstract

Background: Sinus pneumatization is commonly observed following tooth extraction in the posterior maxilla, however, the role of this pneumatization in the overall changes in the vertical bone height is not clear.

Purpose: To compare dimensional changes in the alveolar ridge and corresponding maxillary sinus following tooth extraction, with or without socket preservation.

Materials and Methods: 42 patients underwent tooth extraction (control group) and 21 patients underwent tooth extraction with socket preservation using DBBM (study group). Panoramic radiographs, prior to and approximately 1 year post extractions were superimposed and matched using a fixed reference unit. The following measurements were performed in the midline of the tooth site: distance of the bone crest to the sinus floor; distance of the sinus floor to the sinus roof and the sagittal circumference of the maxillary.

Results: The mean change in the distance from the sinus floor to the sinus roof pre and post operatively was 0.30 mm (± 0.10 SE) in the study group and 1.30 mm (± 0.27 SE) in the control group ($P = .0221$). The mean change in the distance from the bone crest to the sinus floor was 0.32 mm (± 0.09 SE) in the study group and 1.26 mm (± 0.28 SE) in the control group ($P = .0019$), and the mean change in the sinus sagittal circumference was 37.34 mm (± 6.10 SE) and 125.95 mm (± 15.60 SE), respectively ($P = .0001$).

Conclusions: Ridge preservation using bovine derived xenograft might reduce sinus pneumatization along with minimizing crestal bone resorption.

KEYWORDS

bone augmentation, dental implants, sinus pneumatization, tooth extraction, vertical height

1 | INTRODUCTION

Sinus pneumatization is a continuous physiological process that occurs naturally and causes an increase in paranasal sinus' volume.¹ Such pneumatization is also commonly observed following tooth extraction in the posterior maxilla which is sometimes referred to as "disuse atrophy".^{2–4} The decrease in the functional forces that are transferred to the bone following tooth loss, may cause a shift in the remodeling process toward bone resorption (Wolff's law),⁵ which

might lead to an increase of the sinus volume at the expense of the edentulous crestal bone. It is believed that tooth loss induces maxillary sinus expansion, which in extreme cases may lead to a union between the sinus floor and the crest of the remaining bone.⁵ However, the decrease in the vertical dimensions of the edentulous ridge in these sites is also related to alveolar bone resorption. Thus, these two processes (sinus expansion and alveolar bone resorption) result in the marked deficiency that is often observed in the edentulous posterior maxilla.

In a dog study, Rosen and Sarnat reported a larger sinus volume, 6 and 12 months following extraction of all posterior maxillary teeth.⁶ In addition, Sharan and Madjar² found that posterior maxillary tooth extraction in humans caused a downward expansion of the maxillary sinus in relation to fixed anatomic structures.

The rate of resorption of the alveolar bone varies greatly among individuals and tooth position. This may be affected by several factors, such as the presence of infection, previous periodontal disease, the extent of a traumatic injury and the number or the thickness of the bony socket walls.⁷ This process is completed approximately 3–4 months postextraction.⁸

Several procedures have been proposed to reduce alveolar bone loss following tooth extraction.^{9,10} This includes the immediate grafting of the extraction sockets using particulate bone grafts or bone substitutes to maintain the alveolar volume and height via osteoconductive or osteoinductive effect.^{11–13} A variety of materials have been shown to have such a beneficial effect; these include autogenous bone,¹⁴ demineralized freeze-dried bone allograft,^{14,15} freeze-dried bone allograft,^{16,17} deproteinized bovine bone,¹⁸ and alloplastic materials.¹⁹ A recent Bayesian Network meta-analysis showed statistically significant results favoring alveolar socket grafting (MD 1.02, 95% CI 0.44–1.59, P value < .001).²⁰ Likewise, Willenbacher²¹ in yet another meta-analysis showed a mean difference between test (with socket preservation) and control (without socket preservation) groups of approximately 0.91–1.12 mm in bone height.

The role of sinus pneumatization in the overall changes in the vertical bone height following tooth extraction in the posterior maxilla is not clear and currently, no randomized studies are available which clarify its role.

Hence, the aim of this study was to evaluate and compare maxillary sinus and alveolar crest dimensional changes before and after tooth extraction, with or without socket preservation.

2 | MATERIAL AND METHODS

The research protocol was initially approved by the Ethical Committee of Rambam Health Care Campus, Haifa, Israel (approval #0435-15-rmb). 132 Dental files were initially identified of patients who underwent extraction of either the maxillary second premolar, first molar, or second molar at the Department of Periodontology, between July 1996 and March 2016. 74 patients from the initial database, who had both pretreatment (Tb) and at least 6 months postextraction (Tf) panoramic radiographs, were further screened for possible inclusion in the study. All cases of immediate implant placement or intra-operative sinus perforation were excluded from the study. Finally, 63 patients ≥ 20 years of age were included in the study (Figure 1). Of these, 42 underwent tooth extractions only and 21 underwent tooth extraction with socket preservation using demineralized bovine bone xenograft (Bio-Oss, Geistlich AG, Wolhusen, Switzerland).

The standard surgical protocol included atraumatic extraction, socket debridement and primary closure of the soft tissues. Postoperatively, all patients received analgesics (nonsteroidal anti-inflammatory drugs for 3 days) and antibiotics for 1 week (amoxicillin plus clavulanic acid or clindamycin).

Twenty one subjects (14 females and 7 males), aged 31–80 (mean, 59.9 ± 11.3 years) were included in the study group and forty two subjects (27 females and 15 males), age 30–85 (mean, 59.0 ± 12.4 years) were included in the control group. In cases in which multiple extractions were performed, only one site per patient was randomly selected. Three patients (4.8%) exhibited minor complications following tooth extraction: one had severe postoperative pain and two patients had prolonged bleeding.

All the radiographic measurements were performed by one examiner (IL), following several training sessions which included

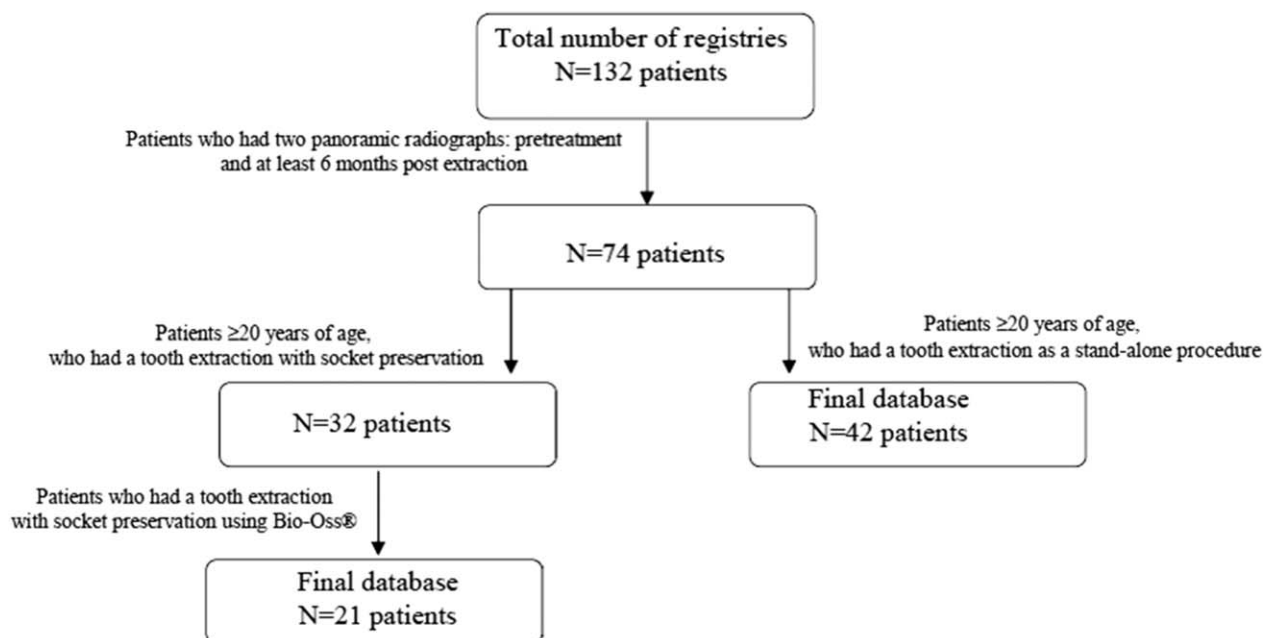


FIGURE 1 Database flow chart

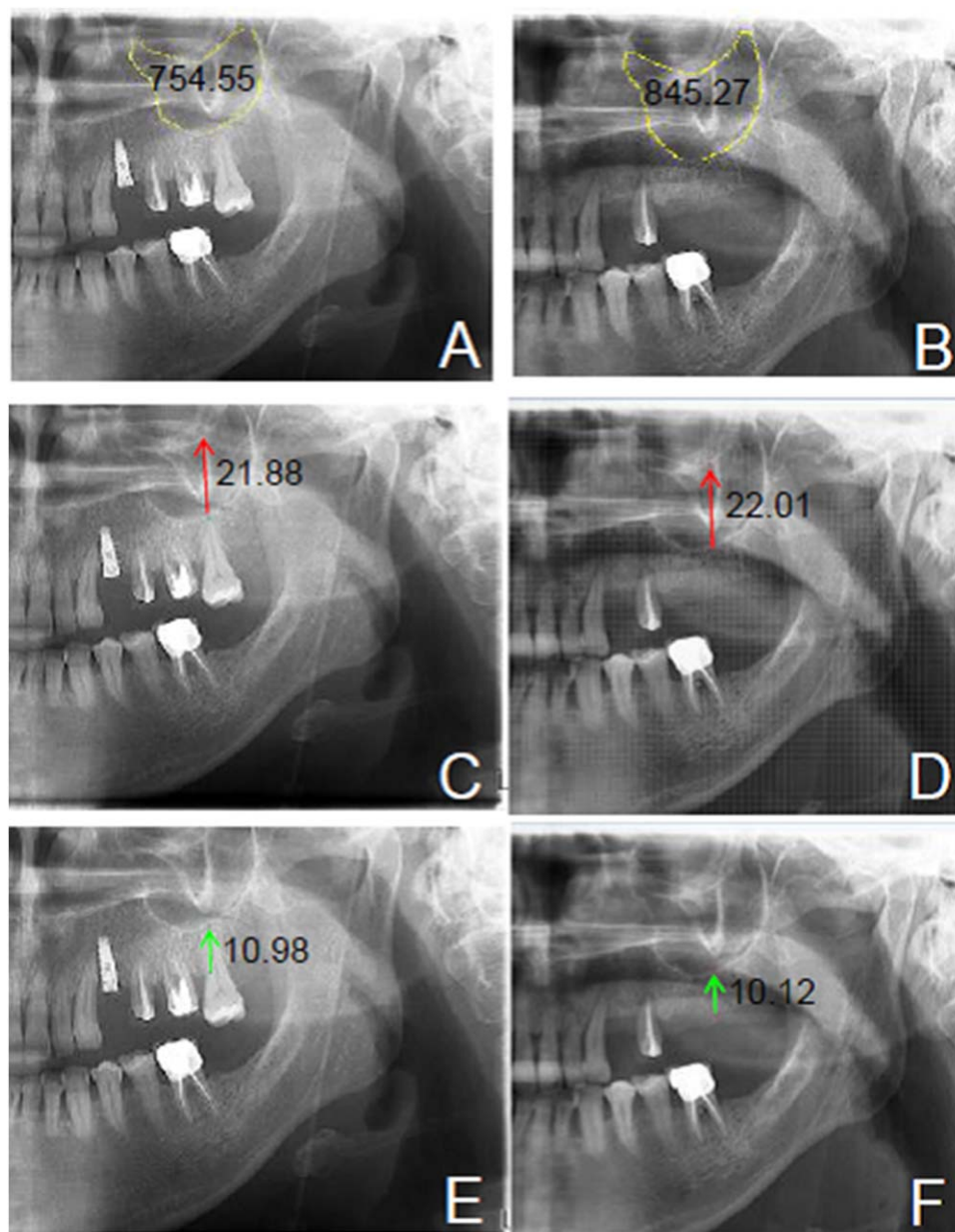


FIGURE 2 Measurements taken before and after the extraction of tooth number 27. Yellow line—Sagittal Circumference, Red arrow—from the Sinus Floor to the Sinus Roof, Green arrow—from Bone Crest to the Sinus Floor. (A) Sagittal Circumference before extraction, (B) Sagittal Circumference after extraction, (C) From the Sinus Floor to the Sinus Roof before extraction, (D) From the Sinus Floor to the Sinus Roof after extraction, (E) from Bone Crest to the Sinus Floor before extraction, and (F) from Bone Crest to the Sinus Floor after extraction

identification of landmarks, matching of radiographs and measurements (see below).

2.1 | Superimposition, matching, and measurements

Matching of the two radiographs was performed to minimize potential distortions which are inherent in panoramic radiography.^{22,23} Power Point software (Microsoft Office 2016) was used to match the two radiographs as follows: the two images were set for transparency and superimposed in the region of interest. Fixed reference structures, such as teeth and dental implants adjacent to the region of interest were selected for the

matching procedure. Visual matching and alignment was performed by stretching or contracting the images until the reference structures were matched as close as possible, both occluso-apically and mesio-distally. Once matched, the radiographs were transferred into the Dimaxis Pro measurement software (Planmeca Oy Helsinki Finland) version 4.1.6 for radiographic measurements. ImageJ software (ImageJ 1.50i, Wayne Rasband National Institutes of Health, Bethesda, Maryland, USA) was used to measure maxillary sinus sagittal circumference. (Figure 2)

The following measurements were performed (Figure 3):

1. Maxillary sinus sagittal circumference—Maxillary sinus wall circumference measured on the panoramic radiograph.

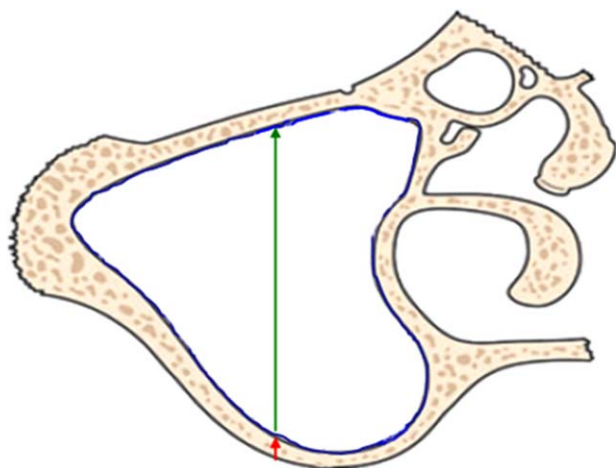


FIGURE 3 Schematic illustration of the measurements taken, Red arrow—from Bone Crest to the Sinus Floor, Green arrow—From the Sinus Floor to the Sinus Roof, Blue line—Sagittal Circumference

- Distance between the bone crest (BC) in the middle of the extraction site and the sinus floor.
- Distance between the sinus floor in the middle of the extraction site and the sinus roof.

2.2 | Calibration

Prior to measurements, calibration was performed. To match the paired radiographs, a fixed reference of known dimension (such as a dental implant and or crown) appearing on both preoperative and postoperative radiographs, was used. In cases in which a fixed reference was not available on both radiographs, the average mean length of an adjacent tooth was used for calibration.²⁴

To account for potential differences between radiographs, after calibration, an additional object which appeared in both radiographs was measured, and the difference between these two measurements was calculated (delta constant). A comparison of the differences between these measurements revealed a mean difference of $0.2 \text{ mm} \pm 0.48 \text{ mm}$.

2.3 | Statistical analysis

Data were analyzed using Minitab Express ver 1.5.0, company Pennsylvania.

Descriptive statistics (mean, SD, percentiles) were tabulated for the categorical and the quantitative parameters. Mann-Whitney test were used to compare between the two treatment groups. To eliminate the effect of multiple observations in a single individual, only one site was randomly selected for each patient for the statistical analysis.

Repeated measures analysis was used to test the equality of the means as within-subjects factor by controlling for categorical depended parameters as between subjects factor or by controlling for independent quantitative parameters as covariate.

Pearson's correlation was used to assess the relation between different quantitative parameters. The level of significance was set at $\alpha = 0.05$.

3 | RESULTS

The study group consisted of 21 subjects while the control group consisted of 42 subjects.

In the study group, extraction sites consisted of 42.8% first molar, 38.1% second molar and 19.1% second premolar, while in the control group, 50%, 26.2%, and 23.8% of the extraction sites were of first molar, second molar and second premolars, respectively. Median follow-up period between baseline and post extraction radiographs was 7 months (range: 6–11 months) in the study group and 9 months (range: 6–36 months) in the control group ($P = .14$).

The mean pre operative sinus height (distance between the sinus floor and the sinus roof) in the study group was $28.59 \text{ mm} (\pm 6.62 \text{ SD})$ and $24.81 \text{ mm} (\pm 7.12 \text{ SD})$ in the control group ($P = .0466$); postoperatively this distance was $28.89 \text{ mm} (\pm 6.55 \text{ SD})$ and $26.12 (\pm 7.27 \text{ SD})$, respectively ($P = .0994$) (Table 1). The differences between pre and postoperative measurements in the study and control groups were $0.30 \text{ mm} (\pm 0.10 \text{ SE})$ and $1.30 \text{ mm} (\pm 0.27 \text{ SE})$. These differences were statistically significant ($P = .0221$) (Table 2).

Mean preoperative ridge height (distance between the BC and the sinus floor) was $8.79 \text{ mm} (\pm 4.18 \text{ SD})$ in the study group and $9.86 \text{ mm} (\pm 4.73 \text{ SD})$ in the control group ($P = .4978$) while post operatively these distances were $8.46 \text{ mm} (\pm 4.05 \text{ SD})$ and $8.59 (\pm 4.73 \text{ SD})$, respectively ($P = .8554$). The mean differences of $0.32 \text{ mm} (\pm 0.09 \text{ SD})$ in the study group and of $1.26 \text{ mm} (\pm 0.28 \text{ SD})$ in the control group were statistically significant ($P = .0019$).

The mean preoperative sagittal circumference of the sinus was $947.48 \text{ mm} (\pm 266.04 \text{ SD})$ in the study group and $1090.11 \text{ mm} (\pm 426.22 \text{ SD})$ in the control group ($P = .2839$) while postoperatively these circumferences were $984.83 \text{ mm} (\pm 271.60 \text{ SD})$ and 1216.05

TABLE 1 Maxillary sinus dimensions before and following tooth extraction

	Group	N	Mean \pm SD	P-value ^a
Pre BC-floor	Study	21	$8.79 \pm 4.18 \text{ mm}$.4978
	Control	42	$9.86 \pm 4.73 \text{ mm}$	
Post BC-floor	Study	21	$8.46 \pm 4.05 \text{ mm}$.8554
	Control	42	$8.59 \pm 4.73 \text{ mm}$	
Pre floor roof	Study	21	$28.59 \pm 6.62 \text{ mm}$.0466
	Control	42	$24.81 \pm 7.12 \text{ mm}$	
Post floor roof	Study	21	$28.89 \pm 6.55 \text{ mm}$.0994
	Control	42	$26.12 \pm 7.27 \text{ mm}$	
Sagittal before	Study	21	$947.48 \pm 266.04 \text{ mm}$.2839
	Control	42	$1090.11 \pm 426.22 \text{ mm}$	
Sagittal after	Study	21	$984.83 \pm 271.60 \text{ mm}$.0695
	Control	42	$1216.05 \pm 471.94 \text{ mm}$	

^aMann Whitney test.

TABLE 2 Changes in maxillary sinus dimensions before and following tooth extraction

	Floor-Roof		BC-Floor		Sagittal circumference	
	Study	Control	Study	Control	Study	Control
N	21	42	21	42	21	42
Mean \pm SE	0.30 \pm 0.10 mm	1.30 \pm 0.27 mm	0.32 \pm 0.09 mm	1.26 \pm 0.28 mm	37.34 \pm 6.10 mm	125.95 \pm 15.6 mm
Median	0.15 mm	1.11 mm	0.15 mm	1.55 mm	31.3 mm	117.83 mm
P value*	.0221		.0019		.0001	

*Mann Whitney test.

(± 471.94 SD), respectively ($P = .0695$). The differences between these mean changes of 37.34 mm (± 6.10 SE) in the study group and of 125.95 mm (± 15.60 SE) in the control group were statistically significant ($P = .0001$).

4 | DISCUSSION

This study suggests that sinus pneumatization following maxillary posterior tooth extraction, might be reduced by socket preservation procedures. To the best of our knowledge, this is the first study that explores the possible association between socket preservation and the extent of sinus pneumatization.

The mean increase in the sinus height was 1.30 \pm 0.27 mm in the nongrafted group compared to 0.30 \pm 0.10 mm in the study grafted group ($P = .022$). These differences were clinically appreciable, and statistically significant.

The values for sinus pneumatization observed in the nongrafted group (1.3 mm) are in agreement with a previous study by Sharan and Madjar² showing an increase of 1.83 \pm 2.46 mm in sinus dimension for the same site pre and post extraction without crestal bone preservation.² Harorh and colleagues³ showed a significant difference in the height of the maxillary sinus between dentate and edentulous cases in favor of the edentulous group. In contrast, Arijji and colleagues,²⁵ who measured the mean transverse and anteroposterior widths of the normal adult maxillary sinuses, found no significant difference between adult subjects with and without maxillary premolars and molars.

It is interesting to note that in all extraction sites, pneumatization of the sinus was accompanied by an additional mean vertical resorption of the crestal bone of 0.32 \pm 0.09 mm (0.15 mm median) in grafted sites and 1.26 \pm 0.28 mm (1.55 mm median), in nongrafted sites ($P = .0019$).

The changes observed in the crestal bone height (BC-Floor), should be interpreted in light of previous studies.^{26,27} A systematic review by Van der Weijden and colleagues,²⁸ reported a mean crestal height change of -1.53 mm 3–12 months post extraction without socket preservation. The vertical changes were predominantly of the buccal prominence, which has been shown to be located 1.2 mm apically to its lingual counterpart. Crestal bone preservation procedures were found to significantly reduce the vertical and horizontal bone dimensional changes. MacBeth and colleagues,²⁹ in a systematic review aimed to measure the effect of crestal bone preservation on linear and

volumetric alveolar site dimensions and found a pooled effect reduction in the midbuccal crestal bone height of only -0.15 mm (95% CI: -0.55 – 0.23) for socket grafting. While in a meta-analysis by Vignoletti and colleagues,³⁰ statistically significant greater values were reported: weighted mean differences were -1.47 mm (95% CI -1.982 , -0.953), $P < .001$.

Studies which compared extraction sites with and without alveolar preservation using mineralized bone-derived xenograft (BDX), showed a linear modification in ridge height generally higher for the untreated sites, with clinical changes ranging from -1.12 to -1.67 mm.^{31,32} Another study by Sbordone and colleagues,³³ analyzed volume changes of postextraction sockets grafted with or without BDX and a resorbable barrier. A significant difference, regarding the percentage of the volume change was registered: a volume loss of 9.9% for the grafted sockets and 34.8% for the nongrafted sockets was found ($P = .0073$).

The limitation of this study is the moderate sample size and the multiple observations within each patient. To negotiate this shortcoming, we randomly selected only one site per patient for the statistical analysis, thus further decreasing the number of observations.

The preservation of the crestal bone seemed to significantly influence the sinus sagittal circumference changes: 125.95 \pm 15.6 and 37.34 \pm 6.10 ($P = .0001$) for the nongrafted and grafted sites, respectively. Differences in methodologies might account for the great variability in previous reports: Takahashi and colleagues,³⁴ used full-body CT images in elderly Japanese cadavers to measure maxillary volumes and to examine the effects of the presence or absence of maxillary molars on maxillary sinus volume change. The volume of the majority of the molar-retained group was 18.4 \pm 5.5 cm³ while the volume for the no molar remaining group was 14.4 \pm 6.8 cm³, $P < .05$. On the contrary, Arijji and colleagues,³⁵ measured normal maxillary sinus volume on axial CT scans and analyzed the findings in relation to the presence of premolar and molar teeth. The volume ranged from 4.56 to 35.21 cm³ (mean 14.71 \pm 6.33 cm³) in patients aged over 20 years. There was no significant difference in patients with and without maxillary premolars and molars. Wagner and colleagues,³⁶ investigated the role of sinus pneumatization and residual ridge resorption in maxillary bone loss in 400 CT scans. They found that prolonged edentulism in the maxillary molar region leads to mainly centripetal ridge resorption and minor pneumatization in the sinus walls, however, the sinus depth underlies the anatomical variation independent of dentition. Velasco-Torres and colleagues,³⁷ investigated the correlation between patient-

dependent variables and dimensional variations of the maxillary sinus using CBCT scans, to measure the total volume of the maxillary sinus. The dimensions of the maxillary sinus were influenced by age and edentulism status, being reduced by aging and tooth loss.

Rosen and Sarnat⁶ compared the volume of the left and right maxillary sinuses in the dog after extraction of teeth adjacent to the left maxillary sinus. In two of the experimental dogs, the volumes of the left and right maxillary sinuses differed only slightly (<3%), while in the other 8 dogs, the differences ranged from 4.6% to 27.1%. In 7/8 animals, the maxillary sinus was larger on the extraction side.

5 | CONCLUSION

Within the limitations of this study, it can be suggested that tooth extraction in the posterior maxilla may lead to sinus pneumatization and crestal bone loss. Ridge preservation using bovine derived xenograft seemed to reduce sinus pneumatization along with minimizing crestal bone resorption. Further studies are required to substantiate these findings and appreciate its magnitude.

CONFLICT OF INTEREST

The authors wish to thank Geistlich Pharma for the donation of the xenogeneic biomaterials used in this study. All authors declare substantial contributions to the design of the work, drafting the paper or revising it and finally approved the version to be published. All authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any parts of the work are appropriately investigated and resolved.

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