BMC Oral Health

RESEARCH Open Access

Short-term retrospective analysis of radiographic evaluation of graft height changes after maxillary sinus floor augmentation with xenograft and simultaneous dental implant placement: a two-dimensional radiographic study

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Abstract

Background Progressive sinus pneumatization, stable sinus graft height and shrinkage of the graft material after maxillary sinus augmentation represent limitations for clinical practice.

Methods Seventy-eight maxillary sinus floor augmentations and 83 dental implant positions were performed on 60 patients. The lateral window approach was used for maxillary sinus floor augmentation. A collagenated porcine bone xenograft (OsteoBiol® Gen-Os®, Tecnoss®, Giaveno, Italy) and a collagen membrane (OsteoBiol® Evolution, Tecnoss®, Giaveno, Italy) were used as grafting materials. Vertical bone gain was analyzed immediately after surgery (T1) and after 4 months (T2) via panoramic radiographic measurements with respect to residual bone height (T0), which was measured preoperatively. Graft height changes were evaluated with respect to implant location, diameter, length, brand and sinus graft width.

Results The mean vertical bone gain per implant following simultaneous maxillary sinus augmentation at sites with a residual bone height of less than 4 mm (11.14 ± 1.87 mm) was the highest among all groups ($p < 0.001$) at the time of baseline surgery. The mean vertical bone gain at the grafted sinus height was significantly lower at 4 months (13.78 ± 1.24 mm) than at baseline (14.58 ± 1.31 mm) ($p < 0.001$). Four months after baseline surgery, a statistically significant decrease of 5.49% in the change in graft height was associated with graft contraction ($p < 0.001$). When the mean graft height changes were compared according to the implant location, diameter, length, brand and sinus graft width, no statistically significant differences were observed ($p > 0.05$).

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Conclusions Within the limits of this retrospective study, collagenated porcine bone xenografts can be used successfully as a sinus augmentation material with simultaneous implant positioning and may contribute to improved graft shrinkage in the short term.

Keywords Xenograft, Vertical bone gain, Bone regeneration, Maxillary sinus floor augmentation, Dental implant, Panoramic radiography

Introduction

Dental implant rehabilitation has proven to be a predictable treatment option for restoring total and partial edentulism. However, the loss of maxillary teeth leads to pneumatization of the maxillary sinus due to the low bone density and expansion in the caudal direction, resulting in a reduction in cancellous bone in the posterior maxilla [1, 2]. Inadequate bone volume and poor bone density in the posterior maxilla represent clinical challenge for the positioning of dental implants [3]. Moreover, conditions such as craniofacial malformations, periodontal disease, trauma, or posttumor therapy may further compromise the alveolar bone volume [4].

Regeneration of the alveolar crest is required to enable positioning of a sufficient number and length of implants at the severely atrophied posterior maxilla [5]. The lack of bone volume and anatomical limitations have been overcome by the development of different surgical techniques, including the use of short and diameter-reduced implants, the positioning of angled implants, zygomatic implants, pterygoid implants, and the augmentation of the maxillary sinus floor augmentation [2, 6].

Sinus floor augmentation was first described by Tatum in 1986 and was published by Boyne and James in 1980 [1, 7, 8]. Transcrestal and lateral window approaches are the main augmentation procedures used [7, 8]. The lateral wall approach involves the stacking of autogenous bone, a bone substitute, or a mixture of these materials beneath the lifted sinus membrane (Schneiderian membrane) through the prepared lateral window [9].

The ideal grafting material should present osteogenic, osteoinductive, and osteoconductive properties and bone remodeling capabilities and serve as a placeholder for the newly formed bone. These advantages have led to autogenous bone grafts being considered as the "gold standard", owing to their osteoinductive and osteoconductive properties as well as not having a risk of immunological rejection [4, 10]. The need for extraoral donor sites for bone grafting, donor site morbidity, potential nerve injuries, limited volume of harvested bone and unpredictable graft resorption are drawbacks that have led clinicians to develop bone substitute materials of various origins, including allografts (from the same species, humans), xenografts (from different species, such as bovine, porcine, or equine), alloplasts (synthetic) or a combination of these materials [10, 11].

Barrier membranes placed concurrently with a graft material were used to contain the graft material inside the prepared surgical site to prevent its migration or dispersion into the soft tissues and to limit soft tissue invasion. Resorbable and nonresorbable membranes are used for graft containment in bone regenerative procedures. Possible infections after exposure and the need for second surgery for removal are potential drawbacks associated with nonresorbable membranes. In that sense, resorbable membranes were preferred to avoid the disadvantages of nonresorbable membranes in sinus floor augmentation procedures [3].

One-stage (immediate) procedures, including sinus augmentation with simultaneous positioning of the implants, or two-stage (delayed) procedures, with primary healing of the augmented graft material at the sinus before implant positioning, are preferred according to the residual bone height underneath the sinus cavity [5, 12]. As the residual bone height of the maxillary sinus determines the surgical augmentation technique, it should be >4 mm to achieve primary stability of the simultaneously placed implants. If not, implant positioning is postponed for 6–8 months to allow healing of the graft material [13].

However, during sinus augmentations, changes in the height and stability of the graft materials over time have been reported with respect to the repneumatization phenomenon [9]. Progressive sinus pneumatization and resorption of the graft material after augmentation are important factors for the stability of sinus graft height and implant success [11]. For that purpose, bone and graft materials have been measured for quantitative evaluation of bone resorption around implants linearly and volumetrically via two-dimensional panoramic radiographs and cone-beam computed tomography (CBCT), respectively [14].

The purpose of this retrospective study was to evaluate short-term 4-month follow-up of collagenated porcine bone xenografts (OsteoBiol®) for changes in graft height following maxillary sinus floor augmentation via the lateral window technique with simultaneous implant positioning in patients with maxillary sinus pneumatization on the basis of radiographic data. Existing standardized panoramic radiographs taken as part of routine clinical procedures were retrospectively analyzed to assess graft height changes to investigate the possible correlation between residual bone height, sinus graft width and

implant variables such as implant location, diameter, length and brand.

Materials and methods

Characteristics and settings of the study

The present retrospective study was conducted on individuals who underwent maxillary sinus floor augmentation and simultaneous dental implant positioning treatment at Dental Implant Clinic A Plus between July 2022 and December 2024. The subjects had panoramic radiographic records, which were used for retrospective radiographic evaluation.

Ethics declaration

The study was approved by the Ethics Committee of Istanbul Gelisim University (Decision Number: 2025-11-04) and clinical procedures were conducted in accordance with the Declaration of Helsinki. Retrospective measurements were made on the panoramic radiographs that had been registered in the system.

Patient selection

In this study, patients were enrolled who lacked sufficient bone for implant positioning without sinus augmentation in the maxillary posterior region were enrolled. Inclusion criteria were as follows: (i) good overall systemic health; (ii) age ≥ 20 years; (iii) local conditions suitable for implant positioning and maxillary sinus floor elevation procedures; (iv) nonsmokers or smokers whose cigarette consumption is limited to ≤ 10 cigarettes per day; (v) insufficient residual bone height (> 2.50 mm) in the premolar or molar region of the maxilla for implant positioning; and (vi) sufficient residual horizontal bone quantity (minimum width of 5 mm). The exclusion criteria were as follows: (i) any general contraindication for implant surgery (e.g. uncontrolled diabetes, hypertension, acute/chronic rhinosinusitis/sinusitis, and allergic rhinitis); (ii) localized contraindications for implant surgery; (iii) acute/chronic sinusitis or other sinus pathologies; and (iii) previous bone augmentation procedures in the maxillary region.

Radiographic analysis

Panoramic radiographs were obtained by the same technician at the appropriate position with 80 kV, 9.0 mA, and 14.0 s irradiation parameters via the standard acquisition protocol with a panoramic X-ray system (de Götzen - Xgenus Aries 2D PAN, Italy). Measurements were performed by a radiologist with at least five years of experience who was not involved in the treatment of the patients, using ImageJ, v.1.53t (National Institutes of Health, USA) [15] with blinded radiographs at each stage. The program was calibrated during the measurement process using the actual implant length for each radiographic image. Patients with poor-quality radiographs and unsuitable head positions were excluded from the study.

The location, diameter, length, and brand of the implants placed were obtained from existing clinical records. Panoramic radiographs that had been previously taken as part of a routine clinical protocol—before surgery, after maxillary sinus floor augmentation with simultaneous dental implant positioning, and during gingiva former placement at 4 months—were retrieved and evaluated retrospectively.

The location, diameter, length, and brand of the implants placed were obtained from existing clinical records. Panoramic radiographs that had been previously taken as part of a routine clinical protocol—before surgery, after maxillary sinus floor augmentation with simultaneous dental implant positioning, and during former gingiva placement at 4 months—were retrieved and evaluated retrospectively. Preoperative radiographs (T0) were used to identify the residual bone height (RBH), defined as the vertical distance from the crest of the edentulous alveolar ridge to the floor of the maxillary sinus (Fig. 1a). The actual implant length was used for calibration of the measurements (Fig. 1b). Postoperative radiographs taken immediately after surgery (T1) were used to measure the sinus graft width (SGW). The SGW was defined as the linear distance between the most mesial and most distal points of the graft material (Fig. 1c). VGH-T1 was defined as the distance from the alveolar crest to the highest bony point near the apex of the implant (Fig. 1d). All the implants were placed via a submerged surgical approach, and after a healing period of 4 months, the gingiva formers were placed via a second implant-uncovering surgery. Follow-up radiographs taken 4 months later (T2) at the second surgery for gingiva former placement were used to measure the vertical graft height at T2 (VGH-T2), defined as the distance from the alveolar crest to the highest bony point near the apex of the implant (Fig. 1e). Vertical bone gain at T1 (VBG-T1) and vertical bone gain at T2 (VBG-T2) were calculated by subtracting the RBH at T0 from VGH-T1 and VGH-T2, respectively. Graft height change was assessed by the difference between VBG-T2 and VBG-T1 at the end of 4 months.

Surgical procedure

Surgical procedures were performed by one surgeon. Among the included patients, maxillary sinus floor augmentation sites with simultaneous dental implant positioning were performed via the following surgical protocol: surgery was performed under local anesthesia (Ultracain D-S forte®, Sanofi/Aventis, Hoechst, Germany). Mucoperiostal flaps were reflected following a crestal incision and vertical releasing incisions allowing lateral access to the maxillary sinus cavity. Maxillary sinus

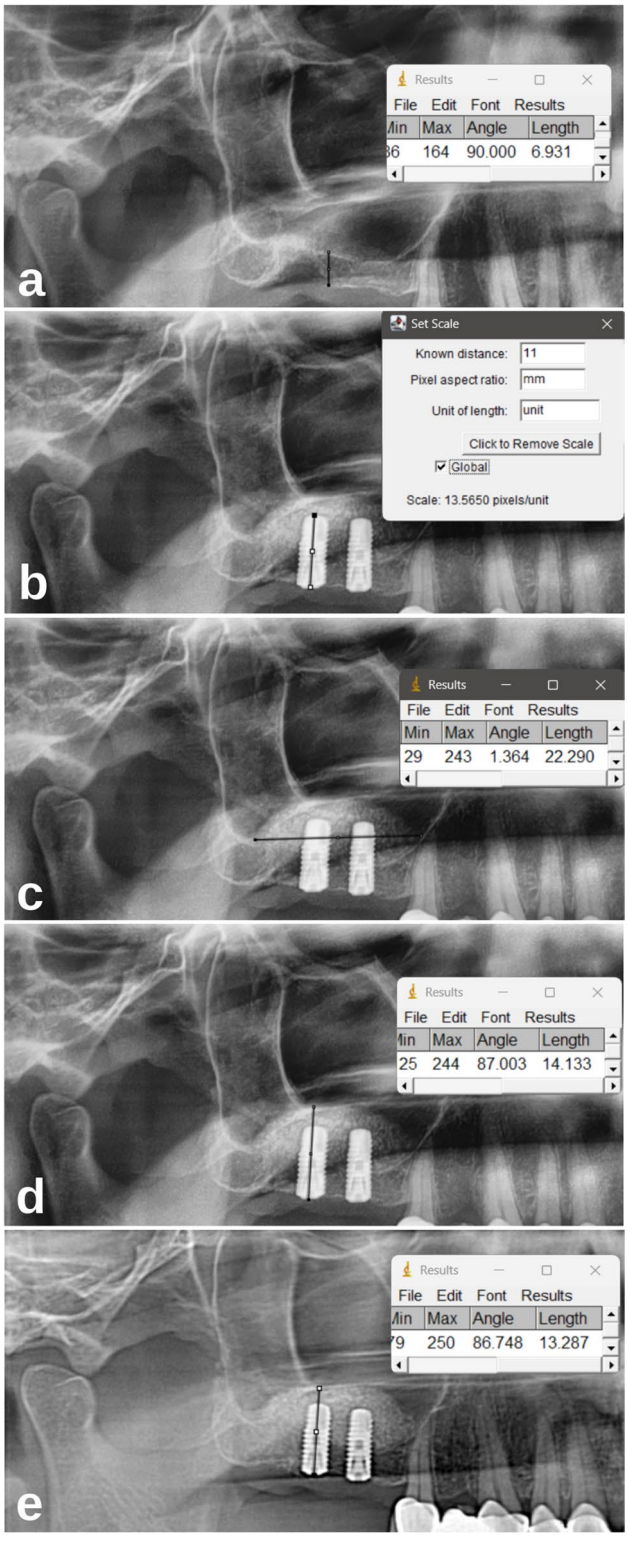


Fig. 1 Panoramic radiographic views of an exemplary participant from the study presenting the radiographic measurements performed via ImageJ analysis: **a** residual bone height measurement, **b** implant length calibration, **c** sinus graft width measurement, **d** vertical graft height measurement at T1, and **e** vertical graft height measurement at T2

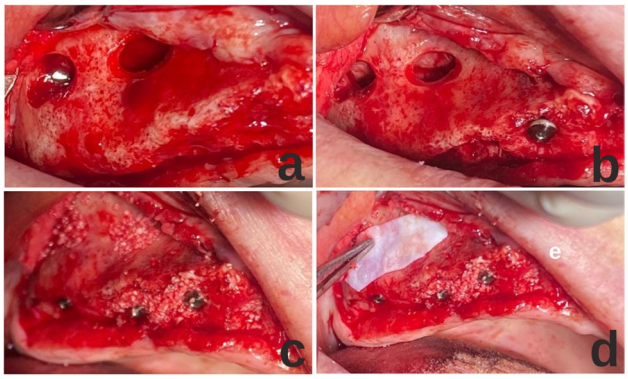


Fig. 2 Clinical view of an exemplary participant from the study: **a** Osteotomy with two lateral windows and elevation of the Schneiderian membrane, **b** application of the collagen membrane underneath the lifted maxillary Schneiderian membrane, **c** application of the graft material into the maxillary sinus cavity and simultaneous positioning of the submerged dental implants, and **d** application of the collagen membrane onto the lateral osteotomy site

window osteotomy was performed at the lateral aspect of the maxillary sinus wall via a handpiece at 20,000 rpm and round tip diamond ball milling cutters under continuous saline irrigation (Fig. 2a). The Schneiderian membrane was lifted, and the collagen membrane was placed underneath the lifted maxillary Schneiderian membrane (Fig. 2b). The maxillary sinus cavity was grafted with a collagenated porcine xenograft bone substitute (OsteoBiol® Gen-Os®, Tecnoss®, Giaveno, Italy), and a collagen membrane (OsteoBiol® Evolution, Tecnoss®, Giaveno, Italy) was placed onto the lateral osteotomy site to prevent soft tissue infiltration with simultaneous dental implant positioning (Fig. 2c, d). There were no cases of membrane perforation during membrane elevation or osteotomy.

Dental implants [Mars TM, Medigma Biomedical GmbH, Wehingen, Germany ($n=43$), Medentika GmbH, Hügelsheim, Germany ($n=19$), RSX-Line BEGO Semados®; BEGO Implant Systems GmbH & Co. KG, Bremen, Germany ($n=15$), Osstem Implant Co., Busan, Korea ($n=6$)] were placed according to the submerged surgical approach at the bone level following the guidelines specified by the manufacturers. The implants were inserted in the region between the first premolar and the second molar. For every intervention, the implant position, brand, diameter, and length were documented. Implants diameters of 4/4.1/4.2 were evaluated as one group, and the distribution of the implant length and implant diameter are shown in detail in Table 1. The tension-free mucoperiosteal flap was repositioned, and continuous locking 3.0 silk sutures were used. The postoperative instructions included antibiotics and analgesics for all the patients; 875 mg of amoxicillin and 125 mg of clavulanic acid every 12 h over five days; and 550 mg of naproxen sodium as needed. The patients were advised to apply

Table 1 Distribution of implant length and implant diameter

Implant Diameter				
Implant Length	**3.75**	**4/4.1/4.2**	**4.5**	**5**
	n	***n***	***n***	***n***
10	5	9	4	1
11	-	5	12	2
11.5	10	28	6	-
13	-	1	-	-

Table 2 Number of patients according to age and sex

Age	Male	Female	Total
26–36	5	-	5
37–47	5	9	14
48–58	13	14	27
59–69	9	5	14
Total	32	28	60

0.2% chlorhexidine mouthwash every 8 h for a period of seven days. The sutures were removed after 7 days. Gingiva formers were placed after 4 months of healing by a second implant-uncovering surgery.

Statistical analysis of data

All the statistical analyses were performed via IBM SPSS Statistics version 23.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics are presented as the means and standard deviations for continuous variables and as frequencies and percentages for categorical variables. The normality of the data distribution was assessed via the Kolmogorov–Smirnov test.

To compare variables between more than two independent groups, the Kruskal–Wallis test was used for nonnormally distributed data, and one-way analysis of variance (ANOVA) was applied for normally distributed variables. Pearson's correlation coefficient was used to evaluate the strength and direction of the linear relationship between continuous variables. Furthermore, multiple linear regression analysis was conducted to determine the independent effects of selected predictor variables on the outcome variable. A p value of less than 0.05 was considered statistically significant for all analyses.

Results

A total of 60 patients (32 males and 28 females, mean age: 49.69 ± 9.70 years, range: 26–69 years) (Table 2) receiving 78 maxillary sinus floor augmentations with simultaneous positioning of 83 submerged dental implants were examined radiographically. Patient data were collected between July 30, 2022, and July 3, 2024, corresponding to a total data collection span of 23 months (mean interval 11.6 ± 6.7 months). Each patient was followed for a period of 4 ± 0 months after the initial procedure, and all follow-up examinations were included in the analysis. Within this date range overall survival rate of implants was %100.

Table 3 Relationship between residual bone height and vertical bone gain at T1

Residual Bone Height	Vertical Bone Gain-T1		
	n	**mean ± SD**	***p****
< 4 mm	5	11.14 ± 1.87	< 0.001
≥ 4 and < 7 mm	50	8.74 ± 1.47	
≥ 7 mm	28	6.75 ± 1.75	

* Significance levels according to Kruskal Wallis test

** Standard deviations

Table 4 Pearson correlation test between implant variables and vertical bone gain at T1

Implant Variables	Vertical Bone Gain-T1	
Implant Length	Pearson Correlation	0.019
	Sig.* (2-tailed)	0.863
Implant Diameter	Pearson Correlation	0.088
	Sig.* (2-tailed)	0.430

* Significance levels according to pearson correlation test

In this study, perforations of the Schneiderian membrane were not detected. All surgical sites healed without any infection or complications. Uneventful osseointegration of all the implants were achieved, and the gingiva formers were placed uneventfully after 4 months. The implant survival rate was 100%.

The mean vertical bone gain (VBG-T1) per implant following simultaneous maxillary sinus augmentation at sites with a residual bone height of < 4 mm (11.14 ± 1.87 mm) was found to be the greatest among all the groups, with a statistically significant difference ($p < 0.001$) (Table 3). When the residual bone height was < 4 mm, compared with patient's residual bone heights between ≥ 4 mm and < 7 mm (8.74 ± 1.47 mm) and those with residual bone heights of ≥ 7 mm (6.75 ± 1.75 mm), statistically significant differences were observed, with p values of 0.012 and 0.01, respectively. These findings demonstrate that the greatest vertical bone gain was achieved at maxillary sinus sites with the lowest initial residual bone height.

Pearson's correlation analysis revealed no statistically significant relationship between implant length and VBG-T1 (correlation coefficient = 0.019, $p = 0.863$). Similarly, no statistically significant correlation was found between implant diameter and VBG-T1 (correlation coefficient = 0.088, $p = 0.430$) (Table 4).

Multiple linear regression analysis was conducted to evaluate the effect of implant-related variables on VGB-T1. The results indicated no statistically significant association for either implant length or diameter ($p > 0.05$) (Table 4). Neither plant length (B = 0.085, $p = 0.805$) nor implant diameter (B = 0.593, $p = 0.422$) significantly influenced VBG-T1 (Table 5).

The mean vertical bone gain at the grafted sinus height (GSH) was significantly lower at T2 (4 months) (13.78 ± 1.24 mm) compared to T1 (baseline)

Table 5 Multiple linear regression analysis for implant variables and vertical bone gain at T1

Implant Variables	Unstandardized Coefficients		Standardized Coefficients	*p**
	B	Standard Error	Beta	
Implant Length	0.085	0.344	0.087	0.805
Implant Diameter	0.593	0.734	0.088	0.805

*Significance levels according to multiple linear regression analysis

(14.58 ± 1.31 mm), indicating a statistically significant reduction of 5.49% over time as a result of resorption in 4 months after initial surgery ($p < 0.001$, Fig. 1).

The mean (VBG-T2) was significantly lower (13.78 ± 1.24 mm) than the VBG-T1 (14.58 ± 1.31 mm), indicating a statistically significant reduction of 5.49% over time as a result of graft shrinkage 4 months after the baseline surgery ($p < 0.001$) (Fig. 3).

The results indicated that there were no statistically significant differences in the mean graft height changes among the groups with different residual bone heights ($p > 0.05$) (Table 6).

When the mean graft height changes were compared according to the implant location, diameter, length, and brand, no statistically significant differences were observed ($p > 0.05$) (Tables 7, 8, 9 and 10).

Sinus graft width did not significantly affect the change in graft height after 4 months (Table 11).

Table 6 Graft height change with respect to residual bone heights

Residual Bone Height (T0)	Graft Height Change	*p**
	mean ± SD	
< 4 mm	−0.90 ± 0.71	0.444
≥ 4 and < 7 mm	−0.73 ± 0.60	
≥ 7 mm	−0.91 ± 0.71	

* Significance levels according to One-Way ANOVA

Table 7 Graft height change with respect to implant location

Implant Location	Graft Height Change		
	n	mean ± SD	*p**
14	3	−0.40 ± 0.21	0.623
15	5	−0.98 ± 1.02	
16	28	−0.93 ± 0.78	
17	5	−0.93 ± 0.19	
24	4	−0.49 ± 0.39	
26	30	−0.74 ± 0.55	
27	8	−0.66 ± 0.52	

* Significance levels according to One-Way ANOVA

Table 8 Graft height change with respect to implant diameter

Implant Diameter	Graft Height Change		
	n	mean ± SD	*p**
3.75	15	−0.62 ± 0.39	0.293
4/4.1/4.2	43	−0.81 ± 0.66	
4.5	22	−0.81 ± 0.66	
5	3	−1.39 ± 0.40	

* Significance levels according to One-Way ANOVA

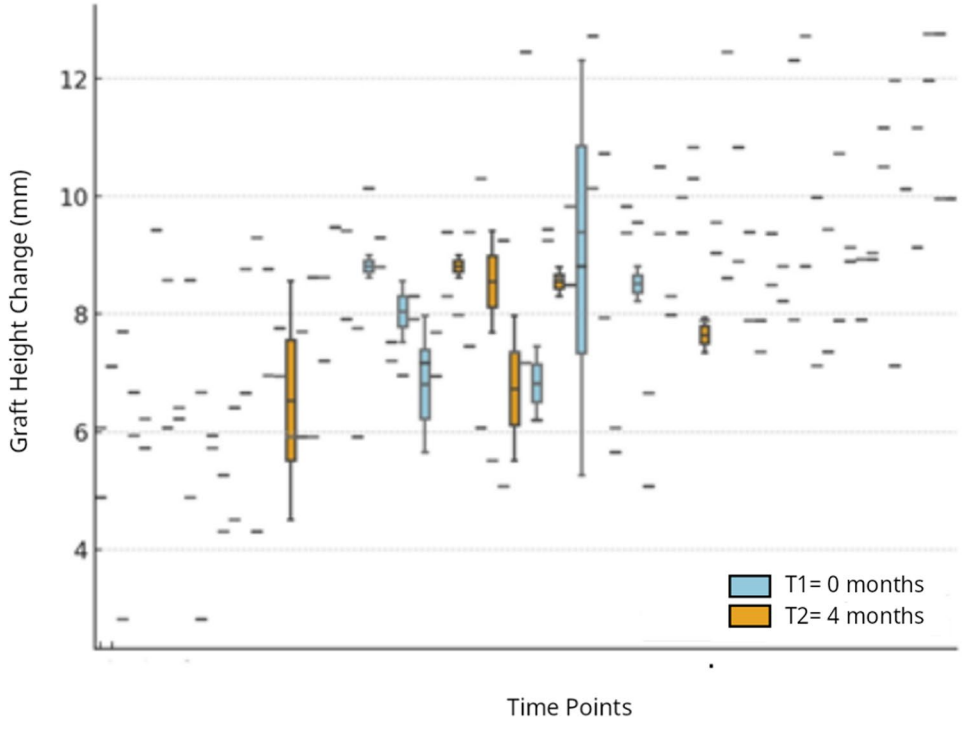


Fig. 3 Boxplot of the change in graft height

Table 9 Graft height change with respect to implant length

	Implant Diameter								
	3.75		4/4.1/4.2		4.5		5		
	Graft Height Change		Graft Height Change		Graft Height Change		Graft Height Change		
Implant Length	*n*	mean ± SD**	*n*	mean ± SD**	*n*	mean ± SD**	*n*	mean ± SD**	*p**
10	5	−0.77 ± 0.07	9	−1.16 ± 0.90	4	−0.69 ± 0.82	1	−0.93	0.063*
11	-	-	5	−1.25 ± 0.69	12	−0.77 ± 0.56	2	−1.62 ± 0.06	
11.5	10	−0.55 ± 0.47	28	−0.63 ± 0.50	6	−1.06 ± 1.06	-	-	
13	-	-	1	−0.25	-	-	-	-	

* Significance levels according to Kruskal Wallis Test

**Standard Deviations

Table 10 Graft height change with respect to implant brand

	Implant Diameter								
	3.75		4/4.1/4.2		4.5		5		
	Graft Height Change		Graft Height Change		Graft Height Change		Graft Height Change		
Implant Brand	*n*	mean ± SD**	*n*	mean ± SD**	*n*	mean ± SD**	*n*	mean ± SD**	*p**
Medentika	-	-	5	−1.25 ± 0.69	12	−0.77 ± 0.56	2	−1.62 ± 0.06	0.396
Medigma	5	−0.62 ± 0.39	30	−0.78 ± 0.71	-	-	1	−0.93	
Bego	10	−0.64 ± 0.48	3	−0.62 ± 0.41	9	−1 ± 0.95	-	-	
Osstem	-	-	5	−0.64 ± 0.31	1	−0.09	-	-	

* Significance levels according to One-Way ANOVA

**Standard Deviations

Table 11 Correlation between sinus graft width and graft height change

	Statistical Values	Graft Height Change
Sinus Graft Width	*r*	−0,154
	*p**	0,165
	n	83

r Spearman Correlation Coefficient

* Significance levels according to Spearman Correlation Analysis

Discussion

The purpose of this retrospective investigation was to determine the radiographic outcome of vertical bone height variations after maxillary sinus floor augmentation with a collagenated porcine bone xenograft (GenOs, OsteoBiol®, Tecnoss®, Giaveno, Italy) combined with a bioresorbable collagen barrier (Evolution, OsteoBiol®, Tecnoss®, Giaveno, Italy) and simultaneous implant positioning over a short-term follow-up period of 4 months. For this purpose, panoramic radiograph measurements were performed before surgery (T0), immediately after surgery (T1), and at 4 months (T2). Graft height changes were analyzed with respect to residual bone height; sinus graft width; and implant location, diameter, length and brand.

There was no statistically significant positive correlation between the mean vertical bone gain and implant length or diameter immediately after maxillary sinus floor augmentation or simultaneous implant positioning (Table 4). The confounding factors were adjusted with multiple linear regression analysis, and the strength of the association between the implant variables and average vertical bone gain was not statistically significant (Table 5). Over a short-term follow-up period of 4 months, the mean vertical graft height changes were not statistically influenced by the residual bone height at T0 or by the implant location, diameter, length or brand (Tables 6, 7, 8 and 9, and 10).

The success of the sinus augmentation procedure depends on the volume and behavior of the graft as well as the residual bone height and quality since the implants take their primary anchorage from this host bone tissue during insertion [16].

The quantity and quality of residual bone under the maxillary sinus floor play important roles in the primary stability of dental implants placed via either submerged or nonsubmerged surgical approaches. If primary stability is achieved, the submerged surgical implant positioning approach with simultaneous maxillary sinus floor augmentation is the treatment of choice since it is a less invasive, more cost-effective and more time-efficient type of surgery [5].

As a consequence of positive intrasinus air pressure produced by respiration, a repneumatization phenomenon could induce bone resorption after the sinus augmentation procedure, leading to graft contraction [9, 17, 18]. As repneumatization of the maxillary sinus cavity takes place, a resorptive decrease in the size of the autogenous bone has to be expected as a disadvantage when used for sinus augmentation [9, 10, 17]. Generally, particulated autogenous bone grafts in combination with

xenografts or alloplastic materials are used as an alternative to reduce the risk of bone resorption following sinus repneumatization. Several bone substitutes for allografts, xenografts and alloplasts have been tested alone for this purpose to exclude the disadvantages of autogenous bone [11, 13, 14, 19]. The clinical regenerative effectiveness of xenografts has been extensively investigated over the years and has demonstrated high predictability, stability, and safety. OsteoBiol® is a cortico-cancellous composite bone substitute material composed of dehydrated granules containing approximately 22% collagen embedded within an organic–mineral matrix [20]. Numerous studies have conclusively shown that collagen plays a crucial role in enhancing angiogenic potential, as well as supporting the proliferation, recruitment, and differentiation of mesenchymal stem cells within the bone marrow [21, 22]. Collagenated bone substitutes have been reported to reduce alveolar bone resorption [23]. During the final stage of the resorption process, the remaining collagen provides nucleation sites that facilitate the mineralization of newly formed bone [24]. Therefore, in this study, a collagenated porcine bone xenograft (OsteoBiol®) was evaluated for its osteogenic potential and stability in supporting implant placement and maintaining the integrity of the augmented sinus graft.

Crestal bone resorption around the implants was not detected since the implants were unloaded and positioned with a submerged surgical approach for a short period of 4 months. Considering residual bone height as a variable, the highest vertical bone gain was achieved in maxillary sinus sites with an initial residual bone height of less than 4 mm, a finding that reflects the intrinsic outcome of the applied surgical technique. Apical bone graft resorption was observed. The change in graft height decreased to a mean of 13.78 ± 1.24 mm from 14.58 ± 1.31 mm after 4 months (Fig. 3). In our study, compared with those in other studies, 5.49% of the collagenated bone xenografts exhibited graft contraction, which was a small percentage; however, this value was expected for the first 4 months of healing. Similar to our study, Scarano et al. [18] tested the volumetric bone changes in this collagenated bone xenograft after maxillary sinus augmentation and presented a small statistical decrease in the volume change of the graft. Other studies measured mean graft contraction rates via various sinus grafting materials via 3D CBCT images at different postoperative times. A prospective clinical study by Dellavia et al. reported a mean tissue contraction volume of 19.17% for autogenous bone and BioOss® at 6 months after one-stage lateral window sinus floor elevation with simultaneous implant positioning [16]. Similarly, another study reported a 26% reduction in autogenous bone, Algipore®, Bio-Oss® or a combination of autogenous bone with these bone substitutes at 6 months [25]. Wanschitz et al. [26] showed a mean volumetric reduction of 13.9% after an observation period of 6 months post-operatively when autogenous bone was used in combination with Algipore®. Favato et al. reported a 19.28% reduction in fresh frozen allogenic particulate bone, hydroxyapatite (Endobon®), 60% hydroxyapatite + 40% beta-tricalcium phosphate (Bone Ceramic®) and Bone Ceramic® + Emdogain® at 6 months [27]. Salem et al. [28] reported a mean reduction in volume of 23.8% for Bio-Oss and 19.5% for cortical mineralized freeze-dried allografts at 6 months. Similarly, Mazzocco and colleagues used inorganic bovine bone (Bio-Oss®) and reported a mean volumetric reduction of 10% after 9 months [29]. In our study, OsteoBiol® presented a relatively low graft shrinkage rate compared with the other studies.

Anatomical variations in sinus morphology and sinus graft width may have an influence new bone formation [30]. Reduced osteogenic potential occurs in wide sinus cavities, whereas in narrow sinus cavities, intimate contact between the grafting material and sinus walls is more likely to be achieved in terms of the buccopalatinal dimension [31]. The reduction in graft height was not significantly influenced by the mediolateral width of the sinus graft or the residual bone height in our results. Pignaton et al. [32] also confirmed that both residual bone height and sinus width were not factors that influenced on new bone formation in sinuses grafted with Bio-Oss® after 8 months of healing.

Panoramic radiographs have previously been used to study bone graft substitutes after sinus floor augmentations and their relationships with dental implant variables and sinus anatomy [12, 33–35]. The borders and localization of the maxillary sinus floor may be difficult to distinguish on two-dimensional radiographs, because of poor visualization [36]. Therefore, since the maxillary sinus floor could not be discriminated, we indirectly measured the residual bone height and augmented vertical graft height to measure changes in graft height. In this study, we calibrated the mean ± standard deviation (SD) using the actual length of the implants in patient who underwent maxillary sinus augmentation with simultaneous implant positioning to overcome this drawback. Computed tomography (CT) can be used with greater measurement precision to identify the outline of the grafted sinus floor and to measure the height and volume of bone available for implant positioning [36, 37]. However, in the present retrospective study, only panoramic radiography was used to assess the bone and graft height changes, since patient cooperation was limited for CT scans in terms of increased radiation exposure and medicolegal reasons. Furthermore, Ozyuvaci et al. [13] found no significant differences in vertical height between the panoramic radiographs and computed topographies [38].

Conclusion

This study has certain limitations. First, panoramic radiographs were used instead of CBCT, which may have limited the accuracy of linear measurements and the ability to assess three-dimensional volumetric changes. Second, the follow-up period was relatively short (4 months), which limits the assessment of the long-term stability and volumetric changes in the graft material. As this was a retrospective study, panoramic radiographs were used on the basis of existing patient records. Importantly, repeated CBCT imaging immediately after surgery and again at four months would have significantly increased patients' radiation exposure. Therefore, further studies with longer follow-up periods and three-dimensional imaging methods are needed to validate and expand the current findings. However, our study is expected to provide valuable insights regarding short-term findings for clinicians working in regions with limited access to advanced three-dimensional imaging techniques, as well as for clinicians working in clinics with high patient turnover.

Abbreviations

CBCT	Cone-beam computed tomography
SGW	Sinus graft width
ANOVA	One-way analysis of variance
VBG	Vertical bone gain
GSH	Grafted sinus height
SD	Standard deviation
CT	Computed tomography

Acknowledgements

Not applicable.

Authors' contributions

SY performed all surgical procedures, contributed to the study concept and design, collected clinical data, and was involved in drafting and critically revising the manuscript.GOU performed all radiographic measurements, contributed to data analysis and interpretation, and participated in drafting the manuscript. All authors have approved the final manuscript and agreed to be accountable for all aspects of the work.

Funding

Not applicable.

Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethics approval and consent to participate This study was approved by the Ethics Committee of Istanbul Gelisim University (Decision Number: 2025-11-04). All collected data was anonymized and stored securely to ensure the privacy and confidentiality of the participants. Throughout the study, the Declaration of Helsinki on Human Rights was adhered to approval and consent to participate. Written informed consent was obtained from all the participants at the time of radiographic imaging.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Received: 30 May 2025 / Accepted: 14 November 2025
Published online: 25 November 2025

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