Original Article

Evaluation of volume changes following lateral window maxillary sinus floor elevation using Minics software

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Background: Significant volume changes at the site of lateral window maxillary sinus floor elevation have been reported 6 months postoperatively, with stabilization thereafter. However, at present, there is no consensus regarding the gold standard to assess the shape and volume of the bone graft site after implantation. This study aimed to analyze volume changes in the lateral window maxillary sinus floor elevation region using Minics software.

Methods: We analyzed 40 patients who underwent lateral window maxillary sinus floor elevation surgery at the Stomatology Department of Binhaiwan Central Hospital, Dongguan, China between 2017 and 2020. Twenty patients underwent lateral window maxillary sinus floor elevation with simultaneous implantation, while 20 patients underwent lateral window maxillary sinus floor elevation with delayed implantation 6 months later. Minics software was used for three-dimensional analysis of the elevation site on the day after surgery (T1) and 6 months after surgery (T2) in both groups.

Results: The elevation site volume was reduced 6 months after lateral window maxillary sinus floor elevation. The differences in the length, width, height from the tip, and volume of the implant between T1 and T2 were statistically significant.

Conclusions: The length, width, height, and volume of the lateral window maxillary sinus floor elevation region were reduced using Minics software, suggesting that the volume of the elevation site should be enlarged as much as possible during the operation to prevent volume shrinkage.

Keywords: Bone graft; maxillary sinus; lateral window maxillary sinus floor elevation; software; three-dimensional volume analysis software

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Introduction

Bone augmentation through maxillary sinus floor elevation is widely used to treat vertical bone deficiency in the maxillary posterior area. Maintaining graft stability during maxillary sinus elevation is key to successful surgery (1-6). Because of changes in the air pressure of the maxillary sinus and absorption of bone graft material, the bone graft site may undergo compensational remodelling in terms of shape and volume. The factors affecting changes in the volume of the elevation region are complex and diverse, and there may also be individual differences. At present, there

is no consensus in this regard; however, numerous studies have suggested that volume change of the grafted site is related to the type of bone graft, sinus gasification, and surgical procedure, among other factors (7,8). The stability of the bone graft material is also important for volume maintenance, and we usually use a biofilm to wrap the bone graft material so that it does not fall apart easily. Several studies have shown significant volume changes 6 months postoperatively, with stabilization thereafter (7-11). At present, there is no gold standard for assessing the shape and volume of the elevation region in the grafted site after implantation, and there is no consensus among studies on this subject (12,13). Cone-beam computed tomography (CBCT) is reliable for the evaluation of bone volume; however, it cannot accurately measure the volume. Therefore, it is necessary to identify a method of measuring volume changes in the maxillary sinus.

Several tools for measuring bone volume are available. "Dolphin" software is used primarily to measure the volume of the maxillary sinus airway, with an error rate of between 9% and 42%. However, the application of this software in the measurement of maxillary sinus bone graft volume has not been reported (14). Only one study in recent years has utilized "Minics" software (Minics version 17.0; Materialise, Leuven, Belgium) to measure the volume of maxillary sinus bone grafts (6). Among the various measurement and analytical software applications currently available, Minics offers the most accurate results (15). As a three-dimensional (3D) volume analysis software, Minics can not only help analyze the airway but can also perform linear measurements of the maxillary sinus elevation region volume in 3D. This study used Minics to measure the maxillary sinus elevation region volume after bone grafting and to analyze the 3D changes in the elevation region volume 6 months after lateral window maxillary sinus floor elevation (LSFE). We present the following article in accordance with the MDAR reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-3110/rc).

Methods

Ethical consideration

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional ethics committee of Binhaiwan Central Hospital (No. 2021096) and informed consent was acquired from all individual participants.

Research participants and measurement methods

Participants in this study were those who underwent LSFE surgery at the Stomatology Department of Binhaiwan Central Hospital between 2017 and 2020. A total of 40 participants (men, 26; women, 14; average age, 48.05±0.6 years) were included. Of these, 20 received LSFE with simultaneous implantation and 20 received LSFE with delayed implantation 6 months later.

The inclusion criteria were as follows: (I) surgical site free of local inflammation; (II) no oral mucosal disease present; (III) no sinus disease present; (IV) hygienic oral environment (full mouth plaque score <20%); and (V) follow-up CBCT performed 6 months postoperatively.

The exclusion criteria were as follows: (I) presence of systemic diseases (cardiovascular disease, coagulation and white blood cell disorders, or metabolic disorders); (II) history of radiotherapy in the head and neck area within 12 months preoperatively; (III) ongoing steroid treatment; (IV) presence of neurological or mental illnesses that may interfere with good oral hygiene; (V) immunodeficiencies, including human immunodeficiency virus infection; (VI) history of smoking (more than 10 cigarettes/day); (VII) drug or alcohol abuse; or (VIII) insufficient compliance.

Patients were divided into 2 groups according to the experimental design: (I) LSFE with simultaneous implantation and (II) LSFE with delayed implantation. Preoperative clinical and radiological examinations were performed. Radiographic examination of the maxillary sinus of each patient was performed using CBCT before the LSFE surgery (T0), immediately after the surgery (T1), and 6 months after the surgery (T2). CBCT scans and volume measurements using Minics were performed by the same clinician for all patients. This reduced measurement errors and considerably improved reliability (*Figure 1*). The following materials were used: bio-absorbable collagen membrane (Heal-All®, Yantai Zhenghai Bio-tech Co., Ltd., China), Tianbo bone powder (Bio-osteon, BEIJING YHJ, Beijing), and an implant system (Straumann, Switzerland; SIC, Switzerland). Minics was used to measure the 3D data and the volume of the maxillary sinus bone graft material at T1 and T2 and analyze the results.

CBCT was performed using the KaVo 3D eXam 3D imaging system (KavoSybron, Germany), with a tube voltage of 70 kV, tube current of 31 mA, scanning time of 23 s, and reconstruction thickness of 0.2 mm.

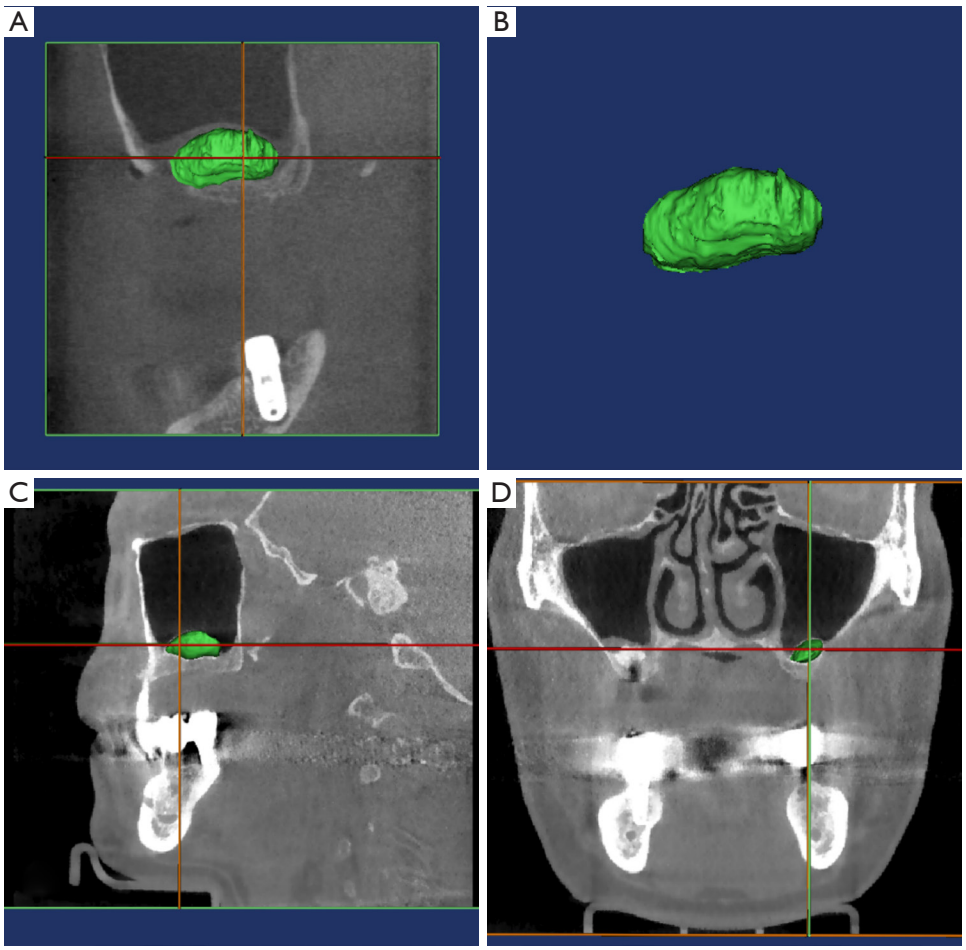

Figure 1 Volume model of maxillary sinus floor bone graft material constructed by Minics. (A) Position map of the three-dimensional reconstruction of the bone graft material at the sinus floor; (B) three-dimensional reconstruction of the bone graft material; (C) sagittal view; (D) longitudinal view.

Statistical analysis

SPSS version 25.0 was used for statistical analysis. A normality test was carried out for continuous data, such as patient age. If the data were normally distributed, data were expressed as mean ± SD. A paired-samples *t*-test was used to compare measured values before and after treatment. Two independent-sample *t*-tests were used to compare the differences in the measured values between both groups. If the variables did not follow a normal distribution, the median (Q1, Q3) was used to describe the variables. The Wilcoxon signed-rank test was used to compare the measured values before and after treatment, and the Mann-Whitney U test was used to compare the difference in the measured values between both groups. Chi-square analysis was used to compare sex-related differences. Differences were considered statistically significant at $P<0.05$.

Results

Comparison of demographic data between the groups

The sex and average age of the participants in the simultaneous implantation group (14 men, 6 women; average age, 49.70±12.44 years) were not significantly different from those in the delayed implantation group (12 men, 8 women; average age, 65.50 years) (Tables S1,S2, *Figure 2*).

Simultaneous implantation group

In the simultaneous implantation group (n=20), the implant length, width, height, and volume at T1 were

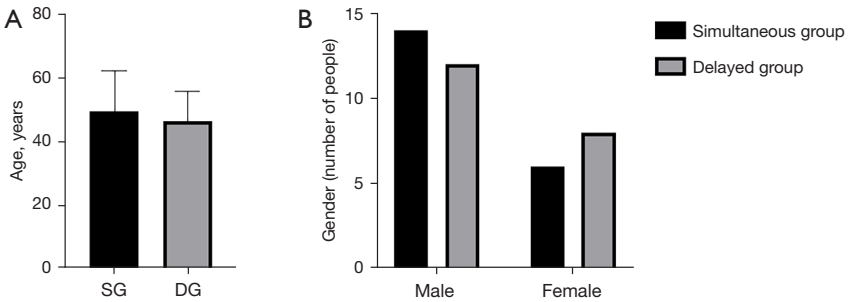

Figure 2 The differences in the sex- and age-related characteristics between the groups. The difference in the sex- and age-related characteristics of the groups is not statistically significant. (P_{Age}=0.507, P_{Gender}=0.512). SG, simultaneous group; DG, delayed group.

18.23±3.74 mm, 16.85±3.07 mm, 11.75±2.33 mm, and 1,258.536±555.50 mm^3 (range, 546.98–2,389.62 mm^3), respectively. The implant length, width, height, and volume at T2 were 16.85±3.99 mm, 14.04±2.98 mm, 9.87±1.85 mm, and 901.7845±410.48 (range, 306.18–1,631.93 mm^3), respectively. The data between T1 and T2 were significantly different (P<0.05).

Delayed implantation group

In the delayed implantation group (n=20), the implant length, width, height, and volume at T1 were 20.64±3.96 mm, 16.37±3.12 mm, 12.32±2.15 mm, and 1521.56±642.27 mm^3 (range, 330.468–2,582.33 mm^3), respectively. The implant length, width, height, and volume at T2 were 19.41±3.80 mm, 14.16±2.79 mm, 10.80±2.13 mm, and 1,102.99±529.09 mm^3 (range, 244.9–1,743.38 mm^3), respectively. The data between T1 and T2 were significantly different (P<0.05) (Tables S3,S4, and *Figures 3*,*4*).

The height from the tip of the implant

The change in height from the tip of the implant was 1.42 (0.35, 2.32) mm in the simultaneous implantation group, while in the delayed implantation group, the change in height was 0.30 (0.16, 0.63) mm. The differences in the values measured immediately and 6 months after implantation were statistically significant (P<0.001). The change in height from the tip of the implant was significant between the 2 groups (Table S5 and *Figure 5*).

Discussion

Minics

Minics, a representative software for manual segmentation, is one of the most commonly used software packages in clinical settings (16,17). Minics can be used for fracture reduction, orthognathic surgery, local plastic surgery, airway lesions, etc. Weissheimer *et al.* demonstrated several advantages in terms of imaging and highlighted the wide range of applications of the Minics software in biomedical engineering (18). Minics' 3D reconstruction and visualization module enables the study of thin-slice CT volumetric datasets in 3 orthogonal planes (transverse, sagittal, and coronal planes), and the image visualization function provides axial, coronal, and sagittal views of the raw data with a reconstructed 3D view, including translation, scaling, and rotation. To date, few studies have been conducted on the application of Minics in measuring volume changes in the LSFE region. We used Minics to evaluate volume changes at the elevation site following LSFE.

Volume changes in the elevation region following LSFE

The factors affecting volume changes in the elevation region post-surgery are complex and diverse, and there may also be individual differences. At present, there are no conclusive findings in this regard. Berberi *et al.* (7) and Kirmeier *et al.* (8) have indicated that the volume changes of bone graft material after maxillary sinus floor elevation are related to the preoperative sinus floor bone mass, bone volume, surgical method, maxillary sinus gasification, and implants, along with the implant material's stability, biochemical properties, absorption mode, and other complex factors. In different studies, the observed volume changes of the same bone graft material can vary greatly, further highlighting that the factors affecting bone graft material absorption are complex and there are individual differences.

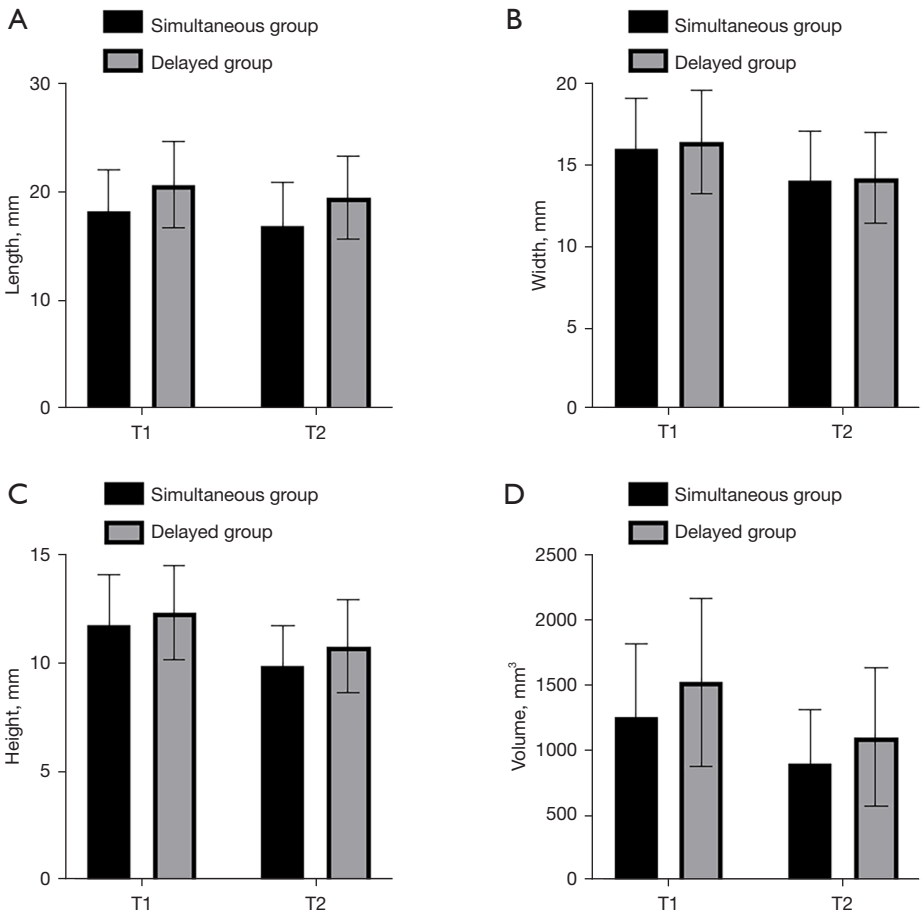

Figure 3 The differences in the length, width, height, and volume of the implant between T1 and T2. The differences in the length, width, height, and volume of the implant between T1 and T2 are statistically significant. (Simultaneous Group: P_{Length}=0.001, P_{Width}<0.0001, P_{Height}<0.0001, P_{Volume}<0.0001; Delayed Group: P_{Length}=0.004, P_{Width}<0.0001, P_{Height}<0.0001, P_{Volume}<0.0001).

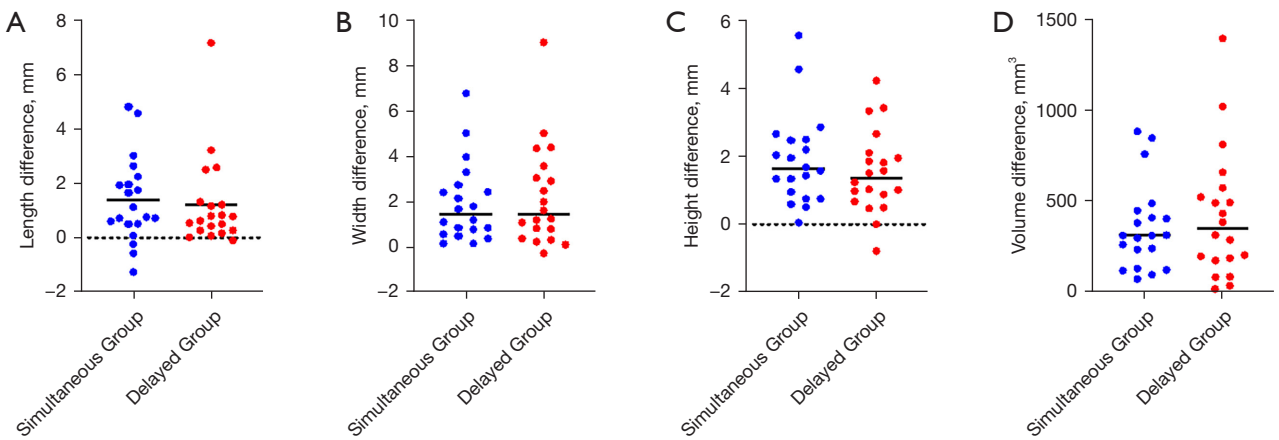

Figure 4 The differences in the length, width, height, and volume of the implant between different groups. The differences in the length, width, height, and volume of the implant between different groups are not statistically significant. ($P_{Length\ difference}$=0.507, $P_{Width\ difference}$=0.86, $P_{Height\ difference}$=0.402, $P_{Volume\ difference}$=0.745).

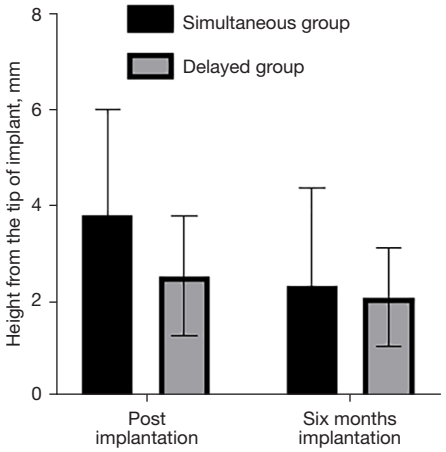

Figure 5 The difference in height from the tip of the implant between different time points. The difference in the height from the tip of the implant between different time points is statistically significant. (P=0.001).

Different types of bone graft material also cause differences in volume changes after maxillary sinus floor elevation. The volume changes with bone substitute materials are less than those of autogenous bone (9); however, they all undergo some degree of reduction following surgery (8,19,20). For this reason, the same type of bone graft material was used for all patients in this study to minimize errors. This study found that 6 months after LSFE, the dimensions and volume of the bone graft in both the simultaneous and delayed implantation groups were reduced. We also detected the interesting phenomenon of an air cavity filled with blood in the elevation region, which was present owing to either the implant or the bone graft material supporting the maxillary sinus membrane. This part exhibited a good osteogenic effect after 6 months, even without the bone graft material, and appeared as normal alveolar bone on the image. It is possible that the maxillary sinus membrane stem cells (MSMSCs) have the characteristics of mesenchymal stem cells, which can differentiate into osteoblasts and participate in the osteogenesis in the sinus floor space after maxillary sinus floor elevation (21). Therefore, in many cases, the actual elevation volume was greater than the graft volume. The average shrinkage percentage of the artificial bone graft in the simultaneous implantation group 6 months after LSFE was 28.14% (range, 8.47–52.00%) and that in the delayed group was 25.64% (range, 2.46–75.69%). These results were similar to those reported by Kirmeier *et al.* (8) where the bone graft volume showed a significant reduction after maxillary sinus elevation. The volume shrinkage percentage (18.3%±2.3%) was similar to that observed by Shanbhag *et al.* (22). Several studies have demonstrated that volume reduction of the bone graft material during the healing period is because of remodelling and contraction of the bone graft material under the sinus floor mucosa. The degree of contraction and remodelling is determined by the bone remodelling characteristics and the degree of vascularization and mineralization of the bone graft material (23,24). With the continuous gasification of the maxillary sinus and absorption of the bone graft, significant changes have been observed in the shape and volume of the bone graft area (7,24). After surgery, the volume of the bone graft is reduced (25-29).

LSFE with simultaneous and delayed implantation

Whether simultaneous implantation can take place during LSFE depends on the volume of the native alveolar bone. The conventional treatment plan requires bone augmentation first when the residual height of the alveolar ridge is less than 4 mm. Once the bone has formed, the implant is placed. The patient must undergo multiple operations, incur high costs, and wait for a long period to complete treatment. However, Peleg *et al.* (30) and Manso *et al.* (31) both found that maxillary sinus elevation and simultaneous implantation may help achieve ideal results and retention rates even when the residual bone volume is less than 4 mm. The presence of less than 4 mm of alveolar ridge height is no longer a contraindication for LSFE and simultaneous implantation. It is possible to maintain the orientation and position of an implant during simultaneous implantation; it does not shift or exfoliate because of inadequate stability during implantation. If the initial stability is adequate, the superstructure can be installed directly, and the non-embedded healing can reduce the need for a second operation and for a period of gingival shaping. If the initial stability is insufficient, a short healing abutment can be installed, and embedded healing can be adopted. In this case, the implant was completely embedded in the mucoperiosteal flap. Following the healing of the mucoperiosteal flap, the implant was pressed against the bone surface owing to the shrinkage of the wound, thereby increasing its stability. Once the osseointegration was complete, the abutment was replaced with one of sufficient height. Pignaton *et al.* also noted that the remaining alveolar ridge height is not the only factor that determines the initial implant stability (32). Simultaneous implantation

may improve preservation of the volume of the bone graft material (33). However, in simultaneous implantation, it is advisable for the graft to be placed up to 2 mm above the tip of the implant and for it to surround the implant to prevent absorption of the material and ensure the stability of the bone at the tip of the implant. The absorption at the tip of the implant with simultaneous implantation is greater than with delayed implantation. When the bone powder at the tip is less than 2 mm, the absorption amount is greater. In the current study, no significant differences were observed in the length, width, height, and volume of the implants between LSFE with simultaneous implantation and LSFE with delayed implantation. This indicates that there are no significant differences between the treatment effects of LSFE with simultaneous implantation and LSFE with delayed implantation in clinical treatment. Nevertheless, simultaneous implantation can reduce the patient's financial burden and the number of operations, as well as shorten the diagnosis and treatment process, allowing patients to regain their mastication abilities swiftly.

There were certain limitations to this study. The sample size may have been inadequate to obtain sufficient postoperative characteristics to establish a change. In future clinical trials, research plans should be designed and implemented more rigorously than our own.

Conclusions

The length, width, height, and volume of the LSFE region were reduced using Minics software. This suggests that the volume of the elevation site should be enlarged as much as possible during the operation to prevent volume shrinkage. There was no difference between the effect of LSFE with simultaneous implantation and LSFE with delayed implantation, although simultaneous implantation is preferred in most cases.

Acknowledgments

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Footnote

Reporting Checklist: The authors have completed the MDAR reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-22-3110/rc

Data Sharing Statement: Available at https://atm.amegroups.com/article/view/10.21037/atm-22-3110/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-3110/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional ethics committee of Binhaiwan Central Hospital (No. 2021096) and informed consent was obtained from all individual participants.

References

1. Zhao R, Yang R, Cooper PR, et al. Bone Grafts and Substitutes in Dentistry: A Review of Current Trends and Developments. Molecules 2021;26:3007.
2. Tartaglia GM, Poli PP, Connelly ST, et al. Clinical Outcome of Dental Implants after Maxillary Sinus Augmentation with and without Bone Grafting: A Retrospective Evaluation. Materials (Basel) 2021;14:2479.
3. Menezes JD, Pereira RDS, Santos AMS, et al. Three-dimensional volumetric changes of 5 different bone grafts in human maxillary sinuses reconstruction: a randomized clinical study. Oral Maxillofac Surg 2021;25:541-7.
4. Lie SAN, Claessen RMMA, Leung CAW, et al. Non-

grafted versus grafted sinus lift procedures for implantation in the atrophic maxilla: a systematic review and meta-analysis of randomized controlled trials. Int J Oral Maxillofac Surg 2022;51:122-32.
5. Afreen S, Kaur T, Rani P. Clinical performance of different bone substitutes in direct and indirect sinus lift procedures for implant placement: a review. Ann Rom Soc Cell Biol 2021;25:758-62.
6. El-Feky AAH. Implant insertion after using of oxidized regenerated cellulose as a graft material in a transalveolar maxillary sinus floor elevation. Res Rep Oral Maxillofac Surg 2021;5:051.
7. Berberi A, Bouserhal L, Nader N, et al. Evaluation of three-dimensional volumetric changes after sinus floor augmentation with mineralised cortical bone allograft. J Maxillofac Oral Surg 2015;14:624-9.
8. Kirmeier R, Payer M, Wehrschuetz M, et al. Evaluation of three-dimensional changes after sinus floor augmentation with different grafting materials. Clin Oral Implants Res 2008;19:366-72.
9. Rios HF, Avila G, Galindo P, et al. The influence of remaining alveolar bone upon lateral window sinus augmentation implant survival. Implant Dent 2009;18:402-12.
10. Nagata K, Fuchigami K, Kitami R, et al. Comparison of the performances of low-crystalline carbonate apatite and Bio-Oss in sinus augmentation using three-dimensional image analysis. Int J Implant Dent 2021;7:24.
11. Jiang Y, Gong M, Chen D, et al. Maxillary sinus pneumatization and augmentation: a three-dimensional finite element analysis. Materials Express 2021;11:1892-900.
12. Shi M. The effect of maxillary sinus anatomical variations, surgical considerations, and patient factors on volumetric changes following lateral wall sinus floor elevation technique for up to 8 years. Birmingham: The University of Alabama at Birmingham, 2022.
13. Comuzzi L, Tumedei M, Piattelli A, et al. Radiographic Analysis of Graft Dimensional Changes in Transcrestal Maxillary Sinus Augmentation: A Retrospective Study. Materials (Basel) 2022;15:2964.
14. de Water VR, Saridin JK, Bouw F, et al. Measuring upper airway volume: accuracy and reliability of Dolphin 3D software compared to manual segmentation in craniosynostosis patients. J Oral Maxillofac Surg 2014;72:139-44.
15. Garcia-Usó M, Lima TF, Trindade IEK, et al. Three-dimensional tomographic assessment of the upper airway using 2 different imaging software programs: A comparison study. Am J Orthod Dentofacial Orthop 2021;159:217-23.
16. Liu R, Yan M, Huang W, et al. Imaging evaluation and clinical controlled study of bone augmentation with cgf in lateral maxillary sinus floor augmentation. Journal of Oral Science Research 2021;37:162-6.
17. Mattos CT, Cruz CV, da Matta TC, et al. Reliability of upper airway linear, area, and volumetric measurements in cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2014;145:188-97.
18. Weissheimer A, Menezes LM, Sameshima GT, et al. Imaging software accuracy for 3-dimensional analysis of the upper airway. Am J Orthod Dentofacial Orthop 2012;142:801-13.
19. Wanschitz F, Figl M, Wagner A, et al. Measurement of volume changes after sinus floor augmentation with a phycogenic hydroxyapatite. Int J Oral Maxillofac Implants 2006;21:433-8.
20. Umanjec-Korac S, Wu G, Hassan B, et al. A retrospective analysis of the resorption rate of deproteinised bovine bone as maxillary sinus graft material on cone beam computed tomography. Clin Oral Implants Res 2014;25:781-85.
21. Songling C, Shuangxi Z. The role of the membrane of the maxillary sinus in space osteogenesis under the sinus floor after elevation of the sinus floor. Journal of Prevention and Treatment for Stomatological Diseases 2020;28:477-86.
22. Shanbhag S, Shanbhag V, Stavropoulos A. Volume changes of maxillary sinus augmentations over time: a systematic review. Int J Oral Maxillofac Implants 2014;29:881-92.
23. Pommer B, Unger E, Busenlechner D, et al. Graft remodeling following transcrestal sinus floor elevation via the gel-pressure technique (GPT) and pasteous nano-crystalline hydroxyapatite bone substitute. Materials 2015;8:3210-20.
24. Stacchi C, Lombardi T, Ottonelli R, et al. New bone formation after transcrestal sinus floor elevation was influenced by sinus cavity dimensions: A prospective histologic and histomorphometric study. Clin Oral Implants Res 2018;29:465-79.
25. Nickenig HJ, Wichmann M, Zöller JE, Eitner S. 3-D based minimally invasive one-stage lateral sinus elevation -- a prospective randomised clinical pilot study with blinded assessment of postoperative visible facial soft tissue volume changes. J Craniomaxillofac Surg 2014;42:890-5.
26. Ohe JY, Kim GT, Lee JW, et al. Volume stability of hydroxyapatite and β-tricalcium phosphate biphasic bone graft material in maxillary sinus floor elevation:

a radiographic study using 3D cone beam computed tomography. Clin Oral Implants Res 2016;27:348-53.
27. Kühl S, Payer M, Kirmeier R, et al. The influence of particulated autogenous bone on the early volume stability of maxillary sinus grafts with biphasic calcium phosphate: a randomised clinical trial. Clin Implant Dent Relat Res 2015;17:173-8.
28. Sbordone C, Toti P, Guidetti F, et al. Volumetric changes after sinus augmentation using blocks of autogenous iliac bone or freeze-dried allogeneic bone. A non-randomised study. J Craniomaxillofac Surg 2014;42:113-8.
29. Mu Z, He Q, Xin L, et al. Effects of injectable platelet rich fibrin on bone remodeling in combination with DBBM in maxillary sinus elevation: a randomised preclinical study. Am J Transl Res 2020;12:7312-25.
30. Peleg M, Mazor Z, Chaushu G, et al. Sinus floor augmentation with simultaneous implant placement in the severely atrophic maxilla. J Periodontol 1998;69:1397-403.
31. Manso MC, Wassal T. A 10-year longitudinal study of 160 implants simultaneously installed in severely atrophic posterior maxillas grafted with autogenous bone and a synthetic bioactive resorbable graft. Implant Dent 2010;19:351-60.
32. Pignaton TB, Wenzel A, Ferreira CEA, et al. Influence of residual bone height and sinus width on the outcome of maxillary sinus bone augmentation using anorganic bovine bone. Clin Oral Implants Res 2019;30:315-23.
33. Lofano B, Luongo R, Bianco G, et al. Vertical alveolar ridge augmentation: a technique for stabilizing bone grafts in the atrophic maxilla with simultaneous implant placement. Medicine Group 2021;2:333-8.

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Supplementary

Table S1 Raw data of 40 patients

Patient	Sex	Age (year)	T1 length (mm)	T1 width (mm)	T1 height (mm)	T2 length (mm)	T2 width (mm)	T2 height (mm)	T1 volume (mm^3)	T2 Volume (mm^3)
Simultaneous Group										
1	Male	73	19.78	20.02	13.03	19.27	18.92	11.69	1,663.19	1,364.65
2	Male	56	17.85	10.19	9.17	14.83	9	7.74	707.85	474.09
3	Male	49	16.34	15.77	13.41	14.59	15.21	10.95	1,116.65	875.52
4	Male	49	16.75	13.87	10.25	16.14	12.19	8.22	931.24	483.59
5	Male	67	16.51	14.12	14.91	17.76	13.64	9.37	813.54	740.33
6	Female	44	11.36	12.93	10.68	11.92	12.56	8.73	546.98	450.48
7	Male	52	23.04	20.25	16.12	22.27	16.29	13.47	2,389.62	1,631.93
8	Female	37	18.21	18.32	12.97	16.55	18.17	12.47	1,452.1	1,329.16
9	Male	39	20.7	16.49	10.2	20.18	15.64	9.45	1,329.63	1,067.65
10	Female	26	16.64	12.95	9.97	14	10.22	9.22	735.1	422.76
11	Male	50	20.53	16.75	10.69	18.28	14.61	9.12	1,240.74	928.68
12	Male	47	18.38	18.57	11.19	17.25	15.28	9.85	1,436.57	1,055.67
13	Male	48	20.33	17.34	15.73	15.76	10.58	11.18	1,629.45	782.21
14	Male	50	19.19	19.61	13.91	19.41	18.84	11.72	1,897.9	1,493.48
15	Male	61	25.85	18.55	13.74	25.12	16.15	10.89	2,248.9	1,365.36
16	Female	25	13.71	12.47	8.24	12.98	11.63	5.75	553.66	422.55
17	Male	59	12.57	12.37	8.98	7.76	9.94	8.39	620.3	306.18
18	Female	47	19.32	18.53	11.61	17.38	13.52	11.56	1,429.94	942.27
19	Male	68	23.94	18.15	10.84	21.98	16.36	9.16	1,699.35	1,290.06
20	Female	47	13.64	12.39	9.38	13.55	12.24	8.43	728.01	609.07
Delayed Group										
21	Male	44	24.74	20.03	13.46	23.52	19.92	13.46	2,653.7	2,456.19
22	Female	48	20.53	14.75	12.39	20.62	14.38	8.97	804.46	721.37
23	Female	50	22.75	16.03	12.7	21.58	16.31	10.6	1,680.35	868.36
24	Male	51	29.59	16.29	11.94	29.31	11.91	11.27	1,498.33	975.78
25	Male	53	18.59	16.67	14.67	17.96	15.48	13.1	1,969.83	1,536.54
26	Male	45	26.23	20.2	15.96	19.08	17.16	11.74	2,582.33	1,562.32
27	Male	48	25.09	16.97	12.72	22.5	15.73	11.49	2,031.95	1,743.38
28	Male	48	22.19	17.74	10.98	21.91	14.84	11.76	1,392.61	1,078.86
29	Male	40	18.11	22.73	11.25	18.03	13.73	10.24	1,240.03	1,035.75
30	Male	52	18.62	12.31	10.55	17.82	12.08	8.61	874.62	686.35
31	Male	43	18.49	11.84	9.67	17.65	11.52	9.2	728.24	710.36
32	Female	64	19.38	12.88	9.72	19.21	12.09	8.69	807.59	770.71
33	Male	19	18.45	12.66	9.74	17.66	11.59	8.24	786.11	611.86
34	Female	33	11.14	12.75	7.43	10.7	9.19	5.62	330.46	244.9
35	Female	43	20.97	20.67	13.69	20.94	16.33	13.2	2,043.64	1,550.6
36	Female	36	19.57	15.23	14.6	18.25	12.76	12.75	1,758.9	1,099.63
37	Male	52	18.68	14.81	12.74	15.46	13.2	10.09	1,547.83	974.79
38	Female	52	23.48	18.47	14.81	22.93	17.65	13.93	2,090.43	1,705.4
39	Female	54	18.35	15.25	13.99	15.85	10.24	10.67	1,839.83	447.19
40	Male	53	17.79	19.11	13.31	17.28	17.12	12.33	1,770.05	1,279.55

Table S2 Comparison of the length, width, height, and volume of the implant between T1 and T2 (comparison within the group)

Variables	Mean	Standard deviation	t	P
Simultaneous Group				
Length	1.38300	1.55790	3.970	0.001**
Width	1.93250	1.74279	4.959	<0.0001***
Height	1.88300	1.34062	6.281	<0.0001***
Volume	356.75150	236.95104	6.733	<0.0001***
Delayed Group				
Length	1.22400	1.66083	3.296	0.004*
Width	2.207950	2.240269	4.408	<0.0001***
Height	1.51800	1.21173	5.603	<0.0001***
Volume	418.57000	350.56945	5.340	<0.0001***

*P<0.05, **P<0.01, ***P<0.001. Paired Student's *t*-test was employed to compare the implant's length, width, height, and volume at T1 and T2; the differences are statistically significant.

Table S3 Comparison of the length, width, height, and volume measured at T1 and T2 (comparison between groups)

Variables	Simultaneous Group		Delayed Group		t	P
	Mean	Standard deviation	Mean	Standard deviation		
T1						
Length	18.2320	3.74352	20.6370	3.95566	–1.975	0.056
Width	15.9820	3.06626	16.3695	3.12069	–0.396	0.694
Height	11.7510	2.32773	12.3160	2.15419	–0.797	0.431
Volume	1,258.5360	555.49845	1,521.5645	642.27321	–1.385	0.174
T2						
Length	16.8490	3.99204	19.4130	3.80077	–2.080	0.044*
Width	14.04950	2.977679	14.16155	2.786717	–0.123	0.903
Height	9.8680	1.84886	10.7980	2.12734	–1.476	0.148
Volume	901.7845	410.48252	1,102.9945	529.09061	–1.344	0.187

*P<0.05. Two independent samples *t*-test was employed to compare the length, width, height, and volume measured at T1 and T2 between groups, the differences were not statistically significant.

Table S4 Comparison of the difference between T1 and T2 data from the simultaneous group and the delayed group

Differences change	Simultaneous Group			Delayed Group			Z	P
	Median	25% quantile	75% quantile	Median	25% quantile	75% quantile		
Length	0.9500	0.5125	2.1775	0.7100	0.2800	1.2950	–0.663	0.507
Width	1.4350	0.6125	2.6550	1.42500	0.47500	3.43000	–0.176	0.860
Height	1.6250	0.8000	2.4825	1.3650	0.7225	2.0600	–0.839	0.402
Volume	312.2000	156.7725	438.0600	349.3900	177.7550	560.4175	–0.325	0.745

Two independent samples *t*-test was employed to compare the difference between T1 and T2 data for implants in the simultaneous group and the delayed group; no statistically significant difference was detected.

Table S5 The comparison of differences in implant height between different groups

Simultaneous/delayed Group	The change of the height from the tip of the implant
Simultaneous Group	1.42 (0.35, 2.32)
Delayed Group	0.30 (0.16, 0.63)
Z	–3.422
P	0.001*

*P<0.05. Mann–Whitney U test was used to compare the difference of the change of the height from the tip of the implant between different groups. The difference is statistically significant.