Efficiency of Static Computer-assisted Sinus Floor Augmentation: A Pilot Study

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Abstract

Lateral sinus floor augmentation is a reliable method to increase bone height in the posterior maxilla for dental implant placement. However, anatomical variations and surgical complexities can complicate the procedure and increase the risk of membrane perforation and vascular injury, consequently extending the duration of the surgery. This study compared the surgical time of static computer-assisted sinus floor augmentation (SCA-SFA) with conventional freehand sinus floor augmentation (SFA). Ten patients requiring lateral sinus floor augmentation were randomized into two groups: SFA (n=5) and SCA-SFA (n=5). Preoperative planning for the SCA-SFA group included cone-beam computed tomography (CBCT) and intraoral scans, with a 3D-printed surgical guide designed to assist the osteotomy. Procedures were performed by a certified specialist, and surgical duration was measured from incision to suture. Statistical analysis was conducted using the Mann-Whitney U test. The results showed no significant difference in overall surgical time between the two groups, with mean durations of 45.96 minutes for SFA and 53.66 minutes for SCA-SFA (p=1.000). The SCA-SFA group required longer times for osteotomy and suturing due to the need for extended flap elevation to accommodate the guide. While the surgical guide provided soft tissue protection, it restricted the visual field, which may have contributed to the increased time. In conclusion, SCA-SFA did not reduce surgical time compared to SFA due to hindrance of visual field. The limitation is its small sample size, and experienced surgeon might not see a significant reduction in surgical time. Future investigations should examine other potential benefits of SCA-SFA, including precision in window osteotomy placement, patient satisfaction, or additional clinical outcomes aside from time efficiency.

Keywords: *surgical guide, guided surgery, computer-assisted surgery, lateral window sinus floor elevation, sinus augmentation, surgical time*

1. Introduction

The lateral sinus floor augmentation is predictable for increasing bone height in posterior maxilla to allow dental implant placement in optimal length. Anatomical variations of the maxillary sinus are frequently found, such as sinus septa, variations in the thickness of the residual alveolar ridge or sinus membrane, arterial anastomoses, a convex maxillary sinus wall, an expanded sinus, and configurations resembling dental roots. These variations can pose intraoperative challenges for the operator during osteotomy of lateral wall of sinus and increase the risk of complications requiring expert intervention, such as membrane perforation, vascular injury, and subsequent hemorrhagic events (Zijderveld et al., 2008).

Currently, Cone Beam Computed Tomography (CBCT) serves as the standard diagnostic tool for planning sinus augmentation procedures. CBCT enables the indirect detection of arteries in the lateral wall of the maxillary sinus, as well as the identification of chronic inflammatory conditions, sinus septa, abnormal membrane linings, ostium closure, sinus configuration, and other factors that may complicate surgery. However, accurately transferring the surgical plan to the patient's anatomy can be challenging when relying on freehand techniques, which would affect the operation time, the incidence of trauma or complications, and the surgeon's confidence. Manually identifying the correct positioning can be time-consuming, thereby extending the duration of the surgery and increasing fatigue for the surgical team.

To address this, Computer-Assisted Surgery has been developed in oral and maxillofacial surgery includes orthognathic surgery planning (Nilsson et al., 2020), mandibulectomy, 3D construction of tumor configuration/fractures in mandible or maxilla and realignment (Zhao et al., 2021), customized block graft (Yen, & Stathopoulou, 2018), implant surgery, surgery rehearsal before surgery (Yao et al., 2019). The Computer-Assisted Implant Surgery (CAIS) has the potential to enhance precision, shorten procedure time, minimize invasiveness, and reduce associated risks, especially in multiple implant placement with flapless technique (Pimkhaokham et al., 2022). However, in raising flap implant surgery, there is no statistically significant difference in time reduction. The development of Computer-Assisted Surgery (CAS) for lateral sinus osteotomy has been designed and reported to help with complex cases and is anticipated to increase accuracy in the sinus region, help reduce intraoperative complications, and potentially reduce the operation time (Mandelaris, & Rosenfeld, 2009; Osman et al., 2018; Zaniol et al., 2018). However, some study reported the operator-assessment that surgical guides prolonged the surgical time (Kocyiğit et al., 2013). Therefore, the main objective of study was to compare the operation time between freehand and static computer-assisted sinus floor augmentation.

2. Objectives

To compare the surgical time of static computer-assisted sinus floor augmentation with conventional freehand.

3. Materials and Methods

3.1 Eligibility Criteria

Medically healthy patients classified as ASA I-II, aged 21 years or older, who sought the placement of 1–2 implants in the posterior maxilla with a residual alveolar bone height less than 3 mm, were consecutively invited to participate in this study. The recruitment took place at the Oral and Maxillofacial Surgery Department, Faculty of Dentistry, Chulalongkorn University, from January to October 2024.

Exclusion criteria included patients with general contraindications for implant treatment or augmentation procedures (e.g., immune deficiencies, corticosteroid use); those taking oral bisphosphonates; or those requiring simultaneous implant placement. Additionally, only non-smokers with no signs of sinus membrane pathology, rhinosinusitis, or other pathologies requiring treatment were eligible, provided they gave written informed consent.

After confirming the treatment plan, patients were randomly assigned to one of two groups using computerized block randomization (block size of 2): the control group (Conventional Freehand Sinus Floor Augmentation, SFA group: N=5) or the intervention group (Static Computer-Assisted Sinus Floor Augmentation, SCA-SFA group: N=5).

3.2 Treatment Planning

All patients underwent radiographic examination using Cone-Beam Computed Tomography (CBCT) (Dentiiscan; Nectec®). After confirming that the residual bone height at the implant sites was less than 3 mm which required staged lateral sinus floor augmentation, the radiographic data were analyzed to evaluate local anatomical conditions, identify potential implant locations, and determine the optimal position for the lateral window. For patients in the SCA-SFA group, an additional intraoral scan was performed using the Trios® 3 (3Shape A/G). The CBCT data in Digital Imaging and Communications in Medicine (DICOM) format and the intraoral scan data in Standard Tessellation Language (STL) format were imported into the implant planning software (coDiagnostiX®) and superimposed. The implant procedure was planned, and a surgical guide was designed to include a frame for guiding the lateral window osteotomy (Figure 1). Then, surgical guide was exported as an STL file to the design software (Meshmixer; Autodesk Inc®) for contouring and smoothing. The finalized design was imported into the printing software (Netfabb; Autodesk®), 3D-printed using dental resin (Straumann® CARES® P10+), and sterilized via autoclaving.

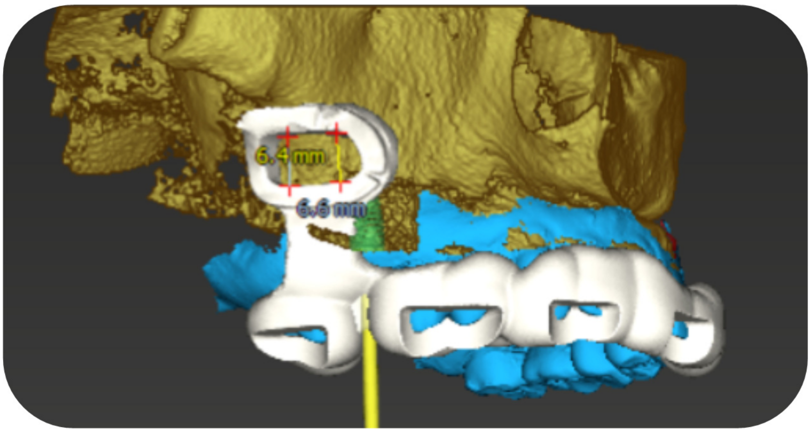

Figure 1 Design of SCA-SFA for lateral sinus osteotomy related to implant area 16

3.3 Surgical Procedures

Before surgery, patients rinsed with a 0.12% chlorhexidine gluconate mouthwash (C20 Plus+, Osoth Inter Laboratories Co., Ltd.) for 1 minute. The procedures were performed under local anesthesia by a certified specialist. The surgical process involved a crestal incision and vertical releasing incisions, followed by the elevation of a full-thickness mucoperiosteal flap to expose the alveolar crest and lateral wall of the maxillary sinus. In the SFA group, the surgeon identified the optimal location for the lateral window osteotomy intraoperatively, guided by prior CBCT measurements. For the SCA-SFA group, a 3D-printed surgical guide supported by at least four teeth was used. After confirming the guide's fit, the lateral window osteotomy was performed through the guide. Rotary or piezoelectric instruments were used to complete the osteotomy, followed by careful elevation of the Schneiderian membrane from the sinus floor (Figure 2). After membrane elevation, deproteinized bovine bone particles sized 1-2 mm (HA Bone®, Novacare Co., Ltd) were packed into the sinus, and a collagen membrane (collprotect® membrane, botiss® biomaterials) was applied to cover the lateral window. The tension-free primary closure using 4/0 absorbable braided sutures was done.

After surgery, patients were prescribed amoxicillin (500 mg, three times daily for 7 days) and ibuprofen (400 mg, three times daily for 3 days). Additionally, patients were advised to use a 0.12% chlorhexidine mouth rinse twice daily for 2 weeks. All surgeries were recorded using a light-mounted camera. The duration of each procedure was determined by analyzing the video timeline, with a single observer measuring the time for each steps from the initial incision to the final suture.

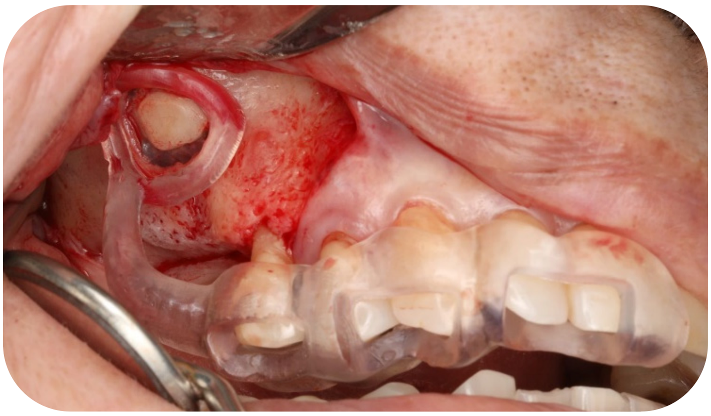

Figure 2 Lateral window osteotomy outline following the surgical guide

3.4 Statistical Analysis

All data were analyzed with SPSS Statistics program for Windows, version 29 (SPSS, Chicago, IL, USA). The Mann-Whitney U test was used to compare the duration of surgery between groups. P-values < 0.05 were considered statistically significant.

4. Results and Discussion

4.1 Result

4.1.1 Baseline Characteristics

A total of 10 patients were screened, enrolled and operated (5 SFA group and 5 SCA-SFA group), while no patients dropped-out during follow-up period.

No significant differences were found between the two groups in terms of patient demographic characteristics, site anatomy, as well as size of the lateral window (Table 1).

Table 1 Baseline characteristics of the patients, site anatomy between two groups

	SFA (N=5)	SCA-SFA(N=5)	TOTAL (N=10)	P-VALUE
Age (Mean(SD))	58.60(15.65)	61.80(7.43)	60.20 (11.67)	0.548(a)
Gender (number of cases)				
Male	3	2	5	0.524 (b)
Female	2	3	5	
Missing Teeth (gap size) (number of cases)				1.000 (b)
1	4	2	6	
2	1	3	4	
Residual Bone Height(mm) (Mean(SD))	1.92(1.07)	2.76(0.79)	2.34(0.98)	0.421 (a)
Width window(mm) (Mean(SD))	10.40(2.51)	13.40(2.70)	11.90(2.92)	0.095 (a)
Height Window(mm) (Mean(SD))	7.80(1.48)	8.80(2.16)	8.30(1.82)	0.222 (a)

SFA, conventional freehand Sinus Floor Augmentation; SCA-SFA, Static computer-assisted sinus floor augmentation (a) Mann-Whitney U-test (b) chi-square exact test

4.1.2 Duration of Procedures

From table 2, the SCA-SFA group showed less time-consuming in sinus membrane elevation, bone graft augmentation, and collagen membrane placement than the SFA group. However, there were no statistically significant differences between the two groups in surgical step durations (p-value > 0.05).

Table 2 Duration of procedures and overall surgery in minutes (mean and standard deviation in parentheses)

Duration (MIN)	SFA (N=5)	SCA-SFA(N=5)	P-VALUE
Flap Elevation	4.95(2.91)	5.79(3.11)	0.69
Window Osteotomy	8.65(6.06)	12.63(6.18)	0.421
Sinus Membrane Elevation	9.76(6.00)	8.57(5.73)	0.841
Augmentation	10.27(7.87)	7.20(5.22)	0.548
Membrane Placement	2.91(2.87)	0.87(0.60)	0.393
Suturing	10.58(5.97)	18.60(17.07)	0.841
Total Time	45.96(17.23)	53.66(29.25)	1.000

SFA, conventional freehand Sinus Floor Augmentation; SCA-SFA, Static computer-assisted sinus floor augmentation; Mann-Whitney U test

4.2 Discussion

The static computer-assisted sinus floor augmentation did not demonstrate a statistically significant reduction in surgical time compared to the conventional method. In fact, it showed a slightly longer total surgical time. The overall duration for SCA-SFA was 53.66 minutes and 45.96 minutes for SFA, which is within the same range as other studies. Scarano et al., (2018) and Baldini et al., (2017) reported the overall duration of lateral sinus lift augmentation to be on average 31.6 $\pm$ 18.0 minutes (Scarano et al., 2018) and 42.62 $\pm$ 6.67 minutes (Baldini et al., 2017), using a small lateral window of 6x6 mm dimensions. Even though the average window dimensions in this study were larger, closer to 12 x 8 mm, the surgical time was not much different according to the time spent on window osteotomy.

SCA-SFA took around 4 minutes longer for window osteotomy than the conventional freehand method though the difference was not statistically significant. This might not be noticeable in specialists who have experience and confidence in window osteotomy positioning, but it may offer more confidence and accuracy for novice operators (Yao et al., 2019; Zhao, & Yam, 2024), considering the learning curve of using a surgical guide

Moreover, suturing time, which accounted for 30% of the overall surgery time in SCA-SFA, was longer than in SFA, referring to the longer incision line that had to be increased to reflect the flap to insert the surgical guide to the lateral wall of sinus. Further study should design a surgical guide to reduce flap incision length and ease on window osteotomy, which reduces thickness of the surgical guide. Although SCA-SFA helps retract and keep the flap away from osteotomy field and protects soft tissue from rotary instruments (Zaniol et al., 2018), it hinders the visual field especially in mesial view Cho et al., (2020). Thus, it might be recommended to remove the superior outline of the surgical guide in order to decrease the need for flap extension (Cho et al., 2020). Zaniol et al., (2018) demonstrated that placing a low window osteotomy position helped to reduce detachment of mucoperiosteal flap while still effectively elevating the membrane and grafting the sinus (Zaniol et al., 2018).

No major intra-operative complications in this study occurred such as loss of augmentation, graft infection, vascular injury, while in 3 cases (1 in SFA and 2 in SCA-SFA) minor perforations of the Schneiderian Membrane occurred during sinus membrane elevation and were repaired by collagen membrane.

Other confounders such as lateral wall thickness of sinus, inability to blind each group to operators, range of mouth opening, quadrant of surgery, and right-handed or left-handed operators may affect the time and complicate procedures, which should further controlled in further research.

In this study, we performed a triangular flap design to place surgical guide, which can be seen in the implant position window osteotomy site. The length of vertical releasing incision was longer in SCA-SFA than SFA. Flap design likes vestibular incision above the window osteotomy site of surgical guide may help reduce wider flap incision and reduce suture time which could reduce post-op pain and swelling. The slightly longer overall time for SCA-SFA may not significantly impact patient outcomes but could be an area for improvement and further investigation to determine whether the longer surgical time of the surgical guide could affect to patient-reported outcomes. Moreover, the impact of static computer-assisted techniques on outcomes such as accuracy of window osteotomy and patient satisfaction should be further studied.

5. Conclusion

The use of static computer-assisted sinus floor augmentation did not reduce the time required for conducting the lateral window osteotomy and the overall time of the surgery due to hindrance of visual field. The limitation of this research is that it is a pilot study which may not be generalizable, and experienced surgeons might not see a significant reduction in surgical time. Future investigations should examine other potential benefits of SCA-SFA, including precision in window osteotomy placement, patient satisfaction, or additional clinical outcomes aside from time efficiency.

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