Comparative study between Computer Guided and Non Guided Lateral maxillary Sinus Lift Procedure with Simultaneous Implant Placement

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Abstract

Objective: Evaluation of the lateral sinus lift technique using 3D-printed surgical guide with simultaneous implant placement.

Design: Prospective comparative study.

Setting: Outpatient Clinics of Oral and Maxillofacial Surgery Department, Faculty of Dental Medicine, Al-Azhar University, Assuit, Egypt.

Grouping: Group I: Lateral Maxillary Sinus Floor Elevation using surgical guide, Group II: Lateral Maxillary Sinus Floor Elevation without surgical guide.

Patients, Participants: Seven patients in each group need for implant placement in the atrophic posterior maxilla, with residual bone height between the alveolar crest and the sinus floor < 6 mm.

Interventions: Using preoperative cone-beam computed tomography (CBCT) and a precise picture of the dentition, a surgical guide was created. Lateral sinus lift was performed by using a 3 dimentional-printed surgical guide for lateral window osteotomy and implant placement. The insertion torque in Newton/Centimeter (N/cm) for each Implant was recorded using a manual calibrated torque gauge ratchet wrench. Implant stability (ISQ) using Osstell® was assessed immediately postoperatively and 6 months postoperatively. Also postoperative pain and any complaints were recorded in visual analog scale (VAS).

Main outcome measures: Ensuring a safer and more precise surgical technique in future one-stage sinus grafting operations.

Results: The insertion torque for each Implant in group I showed a significant increase than group II. Group I showed a significant increase in ISQ at immediate postoperative and six months postoperatively more than group II ($P<0.001$).

Conclusions: Lateral MS floor elevation using a 3D-printed surgical guide with simultaneous implant placement reduces postoperative pain with superior results regarding insertion torque and ISQ.

Keywords: Computer guided-Lateral maxillary sinus lift.

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Introduction

Implant placement in the posterior maxilla might be hindered primarily because of the absence of vertical dimension in the alveolar bone[1]. Multiple factors can impact the posterior maxillary implant placement, such as poor bone quality, as well as posterior maxillary crestal bone resorption associated with maxillary sinus (MS) pneumatization. Several procedures, such as the usage of pterygoid implants, short implants, zygomatic implants, and vertical augmentation employing sinus floor elevation, have been developed to address these issues. Sinus floor augmentation has been regarded as a technique with a good survival rate that provides vertical dimension for posterior maxillary implant insertion [2].

This special condition encountered in the posterior maxilla necessitated a particular procedure, namely sinus augmentation. Sinus floor elevation was proposed to enhance the posterior maxillary bone height. This technique which was firstly conducted in the 1980s by Boyne and James and in 1986 by Tantum, demonstrates remarkable reliability for posterior maxillary vertical augmentation, and thus became a standard approach [3, 4].

Nowadays, the range of approaches has been simplified and unified, and a couple of primary approaches could be identified: lateral antrostomy and crestal approach, with one-staged operation along with simultaneous implant placement or two-staged along with delayed implant placement[5].

Digital dentistry has advanced due to the widespread deployment of cone-beam computed tomography (CBCT). Panoramic film is the most often utilized radiograph in dental clinics, however it can expand measurements by up to 25% [6]. Hence, 3-dimensional radiography is regarded as more effective for identifying the exact width of the MS as well as the alveolar ridge [7], while offering extensive details on sinus and septa pathologies [8].

However, all of the obstacles encountered by dentists during implant surgery can't be resolved with CBCT imaging alone. Even though it assisted the diagnosis and planning a safe operation for the dentists, executing the planned surgery for the precise positioning of the implant remained difficult. A CBCT image-based surgical guide was created and manufactured for implant placement to circumvent the constraint, as it has been observed that using both tools in implant surgery helps to ensure safe and accurate operation [9].

Digital dental advancements have led to the astounding improvement of implant dentistry. In situations needing simultaneous sinus floor elevation and placement of implant, developing higher sophisticated device other than a surgical guide just for implant placement became necessary, especially that a severely atrophic maxilla might pose complications during surgical procedures which necessitates a lateral approach as opposed to a crestal one. Given that sinus augmentation is a rather complex implant dentistry treatment, the advancement of implant surgery requires a surgical guide identifying both the location of the lateral window and the course of the implant. Indeed, several surgical guides' types have been developed for the lateral window opening, but the enormous quantity of the recommended guides and the difficulty of their production were significant drawbacks.

We aimed to define the development and implementation of a computer-planned virtual, 3D printed surgical guide for preparation of guided lateral window osteotomy and implant placement to provide a safer and more precise surgical approach in future single-staged sinus grafting operation.

Materials and Methods

The current prospective trial conducted on fourteen adult human patients of both sexes, seven patients in each group who were collected from the Outpatient Clinics of Oral and Maxillofacial Surgery at the local institution, from April 2021 to April 2022. This research was approved by the local Ethics Committee No (AUAREC202100012-06).

Inclusion criteria were: (1) Healthy adult patients (over 45 years of age), without any systemic complication. (2) Patients missing one or more teeth who need for posterior maxillary dental implant with bone height 4-6 mm below the MS.

Exclusion criteria were: (1) Patients with acute inflammation at the MS. (3) Sinus pathology prohibiting conventional sinus floor elevation which it was excluded on the basis of clinical examination, history and x-ray findings such as: large cyst of the sinus or neoplasm, Acute active sinus infection, previous sinus surgery and presence of bony septa/severe sinus floor convolutions (2) Heavy smokers which could risk implant failure.

CBCT was conducted for evaluation of the maxillary bone and measuring the residual ridge width and height at the implantation area. These measurements were recorded.

Fabrication of a surgical guide:

1. A CBCT scan of the patient's upper and lower jaws, including the MS, was performed.
2. Cast's scanned data was generated as a standard tessellation language (STL) file, meanwhile the CBCT image was saved as Digital Imaging and Communications in Medicine (DICOM) data into the Romexis ™ (VERSION 5.3.5.80 software planmeca machine finland - helinky).
3. The surgical guide designing was followed by the superimposition of the STL file through software to the CBCT data.
4. An adequate implant position was planned after proper adjustment, with creating an open sleeve.
5. In addition, the optimal place for the lateral window was deliberated. Mesiodistal position adjustments were made considering the positions of the sinus septa, third molar, as well as adjacent teeth or implants. The boundaries for the distal and mesial window were adjusted away from the adjacent teeth or implants by at least 1.5 mm. The bottom of the lateral window was formed as low as possible to be flushed with the inferior border of the MS. Figure (1a)
6. After determining the lateral window location, the inferior 3/4 of the window was punched out in the desired size and shape for the opening of the lateral window.
7. The finalized surgical guide design was exported as an STL file and printed on a 3D printer. A flowchart is used to succinctly outline the procedure preceding the operation. Figure (1b)
8. The guide was soaked in sodium hypochlorite for 1 minute for disinfecting, followed by thorough rinsing in distilled water; this was performed three times.

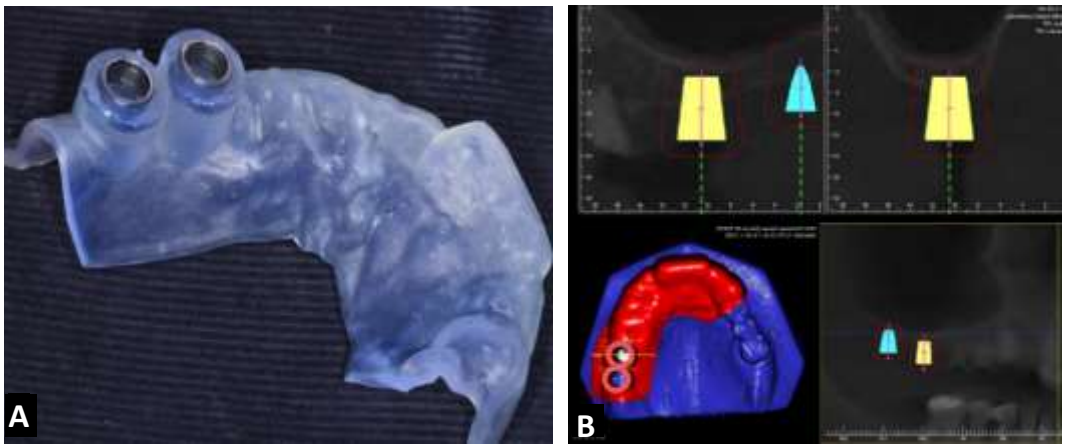

Figure 1: Photograph showing(A) Designing stage of surgical guide for implant and lateral bony window, (B) 3D printed surgical guide .

Surgical procedures:

All cases were prepared for the procedure under local anesthesia as well as scrupulous disinfecting of oral cavity.

The surgical ***procedure*** was initiated by adapting the prefabricated surgical guide to the operative site with firm stabilization. Then, pre-planned implants positions marked using surgical marker, followed by removing the surgical guide, and an incision was created in the marked point at the palatal crestal region, which was expanded, starting at the line angle of the mesial tooth, with a sulcular incision and a vertical incision. If necessary, the extra vertical incision may be done on the distal region in a lateral manner.

A full thickness mucoperiosteal flap was reflected sufficiently to reveal the MS lateral wall in addition to the alveolar crest. Then following the readjustment of the surgical guide to the bone, the appropriate implant locations were marked using a surgical pencil. A pencil was also used to trace the predetermined bone window on the surgical guide. Sinus lateral approach kit[*] was used to create bony lateral window. Figure (2a),(2b) and (2c)

The sinus membrane was then lifted with a sinus elevation curette. Care was taken to prevent iatrogenic perforation. The osteotomy site was prepared through the surgical guide and implant fixtures[†], then placed with the identical surgical guide followed by the bone graft placement[‡] beneath the membrane of the elevated sinus. In cases where the bony plate was preserved, it was used to cover the lateral window. The flap was repositioned and sutured with (3-0) Black Silk suture. Figure (2d)

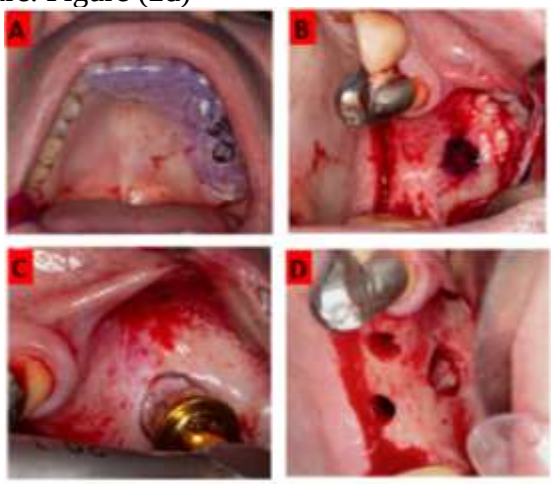

Figure 2: Photograph showing (A) Adaptation of the surgical guide, (B) Demarcated bony window, (C)preparation of the lateral bony windowusing SLA kit (D)osteotomy site and bony window.

Postoperative assessment:

[*] Neobiotech ®: E-space Bldg., 36, Digital-ro 27 gil, Guro-gu, Seoul, 08381, Republic of Korea

[†] TRATE AG, Seestrasse 58, 8806 Bäch, Switzerland

[‡] Nonbone, Artoss GmbH, Fischerweg 421, 18069 Rostock | German

Osstell® device[§] was used to measure implant stability (ISQ) after tightening it to the implant at immediate postoperative and six months postoperative . postoperative pain and discomfort were assessed by VAS .

Statistical analysis:

Data were analyzed using SPSS V.28 for Mac OS (Armonk, NY: IBM Corp). Data was collected, organized in tables and figures, and checked for normality using Shapiro-Wilk at 0.05 level. Data was presented as mean and standard deviation. Difference between observations over time was evaluated using Paired samples t-test and repeated measure ANOVA. Duncan's Multiple Range test (DMRTs) was performed to further compare between more than two timepoints. A two-tailed P-value ≤ 0.05 was deemed significant.

Demographic data

Fourteen patients (14 sinus) were included in our study: seven males and seven females; their ages ranged from 38 to 60 years old. Group I and Group II were represented by seven patients. Group I was represented by 3 males and 4 females, and Group II was represented by 4 males and 3 females. The implant diameters recorded were 3.8, 4.2, and 4.8 mm. In group-I and similarl in group-II. While the implant length recorded was 10 and 12 mm In both groups.

Results:

The insertion torque (N/cm) recorded an average (±SD) 35.0±3.56 and 25.0±3.56 in groups I and II; respectively. The difference between group I and II in insertion torque was significant as revealed by independent t-test. Table (1)

Table 1: Insertion of torque in groups I and II. Data presented as mean and standard deviation. Difference between Groups I and II was assessed using independent samples t-test.

	Insertion torque(N/cm)	
	Group-I	**Group-II**
Mean	**35.0**	**25.0**
SD	3.6	3.6
SE	1.3	1.3
Min	30	20
Max	40	30
T-test Sign.	**<.001*** **	

*, **, ***, significant at p<0.05, <0.01, <0.001; ns, nonsignificant at *p*>0.05

The implant stability Quotient (ISQ) at intraoperative recorded an average (±SD) 61.79±1.87 and 57.14±1.95 in groups I and II; respectively. The difference between group I and II in implant stability Quotient (ISQ) was significant as revealed by independent t-test. The implant stability Quotient (ISQ) at six months postoperative recorded an average (±SD) 79.46±2.35 and 75.29±1.89 in groups I and II; respectively. The difference between group I and II in implant stability Quotient (ISQ)was significant as revealed by independent t-test. Applying two-way repeated measures ANOVA to check the differences induced by groups, time, and group x time. A significant change in ISQ induced by groups (p=0.015) and Time (p=0.001), however interaction between groups and time was nonsignificant Table (2).

Table 2:The implant stability Quotient (ISQ) (mean and SD) at different intervals.

Time point	Implant stability Quotient (ISQ)				T-test Sign.
	Group-I		Group-II		
	Mean	SD	Mean	SD	
Intraoperative	**61.79c**	1.87	**57.14d**	1.95	<.001***
Six months postoperative	**79.46a**	2.35	**75.29b**	1.89	<.001***
Paired t-test	<0.001***		0.003**		
Repeated measure ANOVA					
Group	0.015*				
Time	<0.001***				
Group x Time	0.328 ns				

*, *, ***, significant at p<0.05, <0.01, <0.001; ns, nonsignificant at p>0.05

[§] SmartPeg (Type 57)

a,b Means followed by different letters are significantly different according to DMRTs.

As regarding postoperative pain the visual analogue scale in group-I after 1 week, 1 month, and 2 months recorded an average (±SD) of 6.00±0.87, 0.57±0.53, and 0.00±0.00; respectively. The decrease in VAS with time was significant as revealed by repeated measures ANOVA. While the visual analogue scale in group-II after 1 week, 1 month, and 2 months recorded an average (±SD) of 8.14±1.95, 2.71±1.89, and 0.29±2.89; respectively. The decrease in VAS with time was significant as revealed by repeated measures ANOVA. Table(3)

Table 3: The visual analogue scale in group I and II presented as mean and standard deviation. The difference groups I and II was evaluated by independent t-test. Overall difference was assessed using repeated measure ANOVA.

Timepoint	Pain Score (VAS)				T-test Sign.
	Group-I		Group-II		
	Mean	SD	Mean	SD	
VAS 1 week	**6.00**	0.87	**8.14**	0.75	<0.001***
VAS 1 month	**0.57**	0.53	**2.71**	1.38	0.002**
VAS 2 months	**0.00**	0.00	**0.29**	0.49	0.147ns
RM ANOVA	<0.001***		<0.001***		
Repeated measure ANOVA					
Group	<0.001***				
Time	<0.001***				
Group x Time	<0.001***				

*, **, ***, significant at p<0.05, <0.01, <0.001; ns, nonsignificant at *p*>0.05

Discussion

Due to bone resorption after extraction and limited alveolar bone volume, MS pneumatization, and poor bone quality, posterior maxillary rehabilitation is difficult to accomplish [10]. Sinus floor elevation is a well-established surgical technique assisting implant insertion and prosthetic rehabilitation in an atrophying posterior maxilla [11]. In recent advancements in sinus augmentation, 3D-printed surgical guides and piezoelectric surgery are used[12].

Zaniol et al. [13] stated that the low window sinus floor elevation technique is an advanced approach that uses computer-guided surgery for efficient access and elevation of the sinus membrane, with minimizing the surgical duration and risks including perforation of the sinus membrane.

Our primary objective was to assess the safety and efficacy of the computer-guided lateral sinus lifting approach with simultaneous implant placement. The patients chosen lacked systemic illnesses that might complicate the surgical operation and hinder the recovery process.

In the current trial, treatment planning using CBCT was conducted for designing the dimensions and location of the low window osteotomy. The MS floor and anterior wall are determined and the window design is planned accordingly. As regard the window size and the placement of the inferior horizontal antrostomy line, researchers have differing perspectives. Despite the fact that some researchers recommend putting it close to the sinus floor, others recommend a higher positioning than the floor by 2 to 3 mm [14].

In the present trial, a stereolithographic surgical guide was created preoperatively using the CBCT of the patient and diagnostic cast, considerering the vertical bone density, width, height, angulations of opposite and adjacent natural teeth, and establishing an accurate maxillamandibular relationship for precise implant positioning, in addition to planning and designing the low window based to the protocol already established.

In our research, the average height of the alveolar ridge below the MS floor prior to surgery was 4-6 millimetres. This agreed with Nedir et al. [15], who showed that the presence of a 2-millimeter-length layer of cortical bone is the bare minimum need for ensuring primary implant stability.

In this trial, Nanobone®, a deproteinized bovine bone mineral with a high tensile strength of around 40 Mpa, was used. Nanobone is newly created and approved granular substance composed of nanocrystalline hydroxyapatite embedded in a silica gel matrix that provides a number of the benefits of nanostructural biomaterials. It has very enormous interior surface area (about 84 m^2/g) due to the open silicone oxide (SiO) or silicone hydroxide (SiOH) groups of polysilicic acid. The diameter of interconnecting pores in the silica gel range in size from 10 to 20 nm, causing material porosity of around 60%. It also possess a very rough surface of the granules, creating a micrometer- to millimeter-scale interconnected porous structure [16].

Postoperative clinical assessment in this trial reported absence of sinus membrane tearing, infections, pain, or other surgical complications. Also, patients had an uneventful healing with minimal facial swelling and a high degree of satisfaction. Which agreed with Zaniol et al.[13]. The average ISQ immediately following implant placement and six months postoperatively was (±SD) 61.79±1.87 and 79.46±2.35 respectively, revealing a significantly increased ISQ six months postoperative compared to immediate postoperative ISQ ($P<0.001$). Jelušić et al. [17] reported similar outcomes.

Concerning the postoperative clinical evaluation in this study, it was found that patients in group I had moderate pain and swelling on 2nd day after the operation and no pain after 1 month. While patients in group II had severe pain on 2nd day after the operation ,mild pain after 1 month and no pain after 2 months. Postoperative pain was due to the long operation time, which consequently results in more surgical trauma for soft and hard tissues. a retrospective case series, Zaniol et al. (2018) [18] used sinus floor elevation templates to test the low window sinus elevation technique proposed earlier by the group. No occurrences of sinus membrane tearing, pain, infections or other surgical complications .

Limitations: The large volume of the surgical guides and the complexity of their fabrication technique were major drawback. So, further trials with a longer follow-up duration and larger sample size are required for assessing the final outcomes of both approaches and evaluating their performance and patient-related outcomes.

Conclusion

Lateral MS floor elevation using a 3D-printed surgical guide with simultaneous implant placement provides a faster operation and ensures predictable results, with superior implant stability (ISQ).

Research ethics and patient consent: The research was authorized by the local ethics committee. Any procedures were conducted in line with the ethical requirements of the local ethical committee and with the complete declaration and all subsequent changes to the declaration. All patients received information on the scope of the study and signed an informed consent form.

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