



## Qualitative Analysis of Maxillary Sinus after Guided Lateral Sinus Lift Procedure with Simultaneous Implant Placement

Ahmed Mohamed Zewail <sup>\*1</sup>, Mohsen Fawzy Aboelhasan<sup>1</sup>, Abdel Aziz Baiomy Abdullah <sup>1</sup>,  
Mohamed Mahgub El-Ashmawy <sup>1</sup>, Arfa GadAllah Ibrahim <sup>1</sup>

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Aadj@azhar.edu.eg

### KEYWORDS

Maxillary Sinus,  
Guided Lateral Sinus Lift,  
Simultaneous Implant Placement,  
Piezo surgery, ISQ,  
Dental Implant.

### ABSTRACT

**Aim:** Evaluation of the lateral sinus lift technique using 3D-printed surgical guide with simultaneous implant placement. **Subjects and methods:** 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 dimensional-printed surgical guide for lateral window osteotomy and implant placement. CBCT was obtained and maxillary sinus volume (MSV) was measured preoperatively, immediately postoperatively, and 6 months postoperatively. Implant stability (ISQ) using Osstell® was also assessed immediately postoperatively and 6 months postoperatively. **Results** MSV Immediate postoperative showed a significant decreased from the preoperative. Moreover, 6 months postoperative showed significant decrease from preoperative ( $p < 0.001$ ). Buccal showed a significantly more bone gain than palatal in immediate and after 6 months postoperative ( $P < 0.05$ ). A significantly increased bone density and ISQ six months postoperatively was reported compared to immediate postoperative bone density and ISQ ( $P < 0.001$ ). **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 sinus volume preservation, bone density, and ISQ.

### INTRODUCTION

Implant placement in the posterior maxilla might be hindered primarily because of the absence of vertical dimension in the alveolar bone <sup>1</sup>. 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 <sup>2</sup>.

1. Department of Oral and Maxillofacial Surgery, Faculty of Dental Medicine, Al-Azhar University, Assuit, Egypt.

\* Corresponding Author e-mail:  
ahmedzewail871@gmail.com

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 Tantom, demonstrates remarkable reliability for posterior maxillary vertical augmentation, and thus became a standard approach <sup>3,4</sup>.

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

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% <sup>6</sup>. Hence, 3-dimensional radiography is regarded as more effective for identifying the exact width of the MS as well as the alveolar ridge <sup>7</sup>, while offering extensive details on sinus and septa pathologies <sup>8</sup>.

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 <sup>9</sup>.

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 case series trial conducted on seven human adult patients of both sexes, who were collected from the Outpatient Clinics of Oral and Maxillofacial Surgery at the local institution, from April 2021 to August 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.

### Surgical procedure:

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 mucoperiosteal full thickness flap was reflected sufficiently to reveal the lateral wall of the MS 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 (Neobiotech®: E-space Bldg., 36, Digital-ro 27 gil, Guro-gu, Seoul, 08381, Republic of Korea) was used to create bony lateral window. Figure (2a) and (2b)

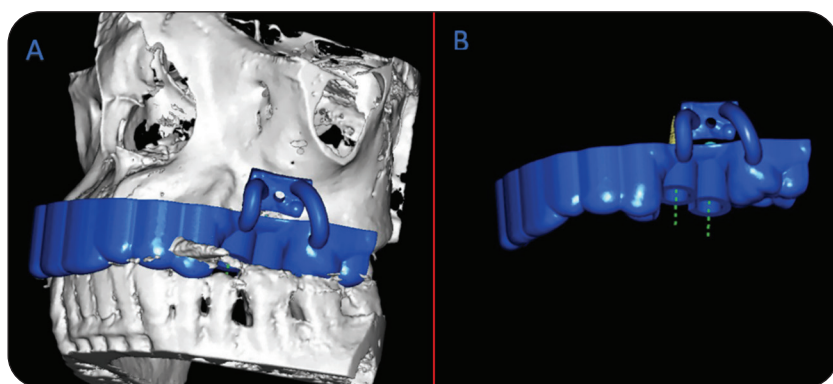


Fig. (1) Photograph showing(A) Designing stage of surgical guide for implant and lateral bony window, (B) prefabricated surgical guide before printing.

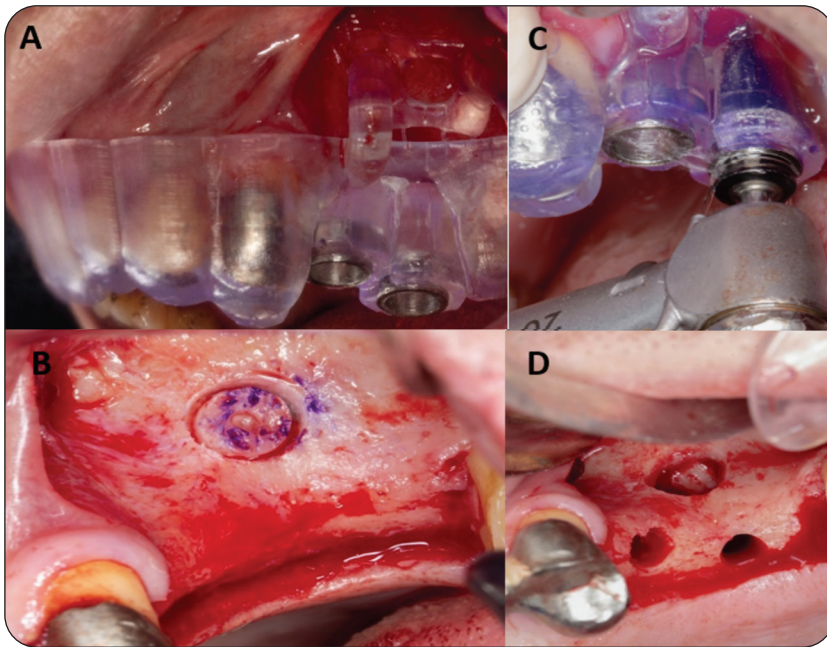


Fig. (2) Photograph showing (A) Adaptation of the surgical guide, (B) Demarcated bony window, (C) Preparation of the osteotomy site through surgical guide, (D) osteotomy site and bony window.

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) TRATE AG, Seestrasse 58, 8806 Bäch, Switzerland, then placed with the identical surgical guide followed by the bone graft placement (Nonbone, Artoss GmbH, Fischerweg 421, 18069 Rostock | German) 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(2c) and(2d)

#### Postoperative assessment:

The MS volume measurements using CBCT scan were performed at preoperative, immediate postoperative and 6 months postoperative. Digital Imaging and Communications in Medicine (DICOM) format was used to export data from CBCT scans into the Romexis™ (VERSION 5.3.5.80 software planmeca machine Finland-helinky) for image analysis and sinus tracing for volumetric measurements. Osstell® device (SmartPeg (Type 57)) was used to measure implant stability (ISQ) after tightening it to the implant. On the palatal and buccal sides of the implant, bone gain was assessed using cross-sectional cuts parallel to the long axis of the implant, followed by bone density assessment in the same plane. Figure (3a,b)

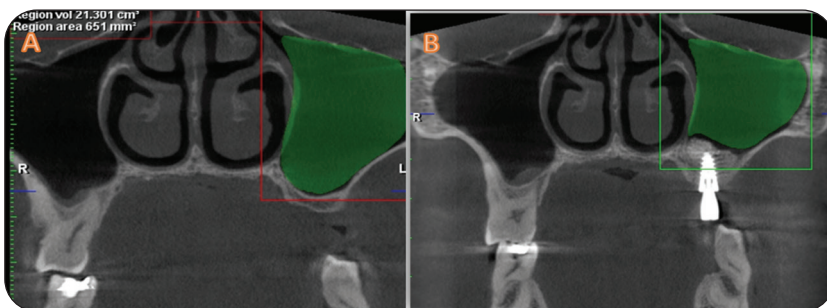


Fig. (3) Coronal view showing (A) Pre-operative maxillary sinus volume, (B) 6 months postoperative maxillary sinus volume

### Statistical analysis:

Data were analyzed using computer software Statistical Package for Social Science SPSS (IBM 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  $\leq 0.05$  was deemed significant.

### RESULTS

The MS volume (MSV) was recorded as mean, standard deviation and change % from the preoperative reading. The MSV in preoperative, immediate postoperative, and 6 months postoperative showed an average ( $\pm$ SD) of  $18.55 \pm 1.87 \text{ cm}^3$ ,  $17.34 \pm 2.35 \text{ cm}^3$ , and  $17.46 \pm 3.35 \text{ cm}^3$ . The difference in MSV between time points was highly significant. Immediate postoperative showed a significant decrease by 6.54% from the preoperative. Moreover, 6 months postoperative showed a 5.88% significant decrease from preoperative ( $p < 0.001$ ). No significant difference was reported between MSV immediately postoperative and 6 months postoperatively. Table (1)

**Table (1)** The Maxillary sinus volume was recorded as mean, standard deviation and change %

Time point	MSV( $\text{cm}^3$ )		
	Mean	SD	% change
Preoperative	18.55 <sup>a</sup>	1.87	--
Immediate postoperative	17.34 <sup>b</sup>	2.35	-6.54*
6 months postoperative	17.46 <sup>b</sup>	3.35	-5.88*
Repeated measures ANOVA	<0.001***		

\*, \*\*, \*\*\*, significant at  $p < 0.05$ ,  $< 0.01$ ,  $< 0.001$ . Intragroup comparison using repeated measures ANOVA. a,b means followed by different letters are significantly different according to DMRTs.

The bone gain at immediate postoperative buccal, immediate postoperative palatal, 6m postoperative buccal, and 6m postoperative palatal recorded an average of  $10.32 \pm 1.87 \text{ mm}$ ,  $10.84 \pm 2.35 \text{ mm}$ ,  $9.84 \pm 3.35 \text{ mm}$ , and  $10.38 \pm 4.35 \text{ mm}$ ; respectively ( $p < 0.001$ ). The difference in bone gain between study time points was significant. In the buccal, the immediate bone gain ( $10.32 \pm 1.87 \text{ mm}$ ) was significantly reduced after 6-months ( $9.84 \pm 3.35 \text{ mm}$ ) as evaluated by paired samples t-test. In palatal, the immediate bone gain ( $10.84 \pm 2.35 \text{ mm}$ ) was significantly reduced after 6-months ( $10.38 \pm 4.35 \text{ mm}$ ). Moreover, Buccal showed a significantly increased bone gain than palatal in immediate and 6 months postoperative ( $p < 0.05$ ). Table (2)

**Table (2)** The bone gain immediately postoperatively and 6 months postoperatively

Timepoint	Bone gain (mm)		Paired t-test (p-value)
	Buccal	Palatal	
Immediate	$10.32 \pm 1.87$ <sup>ab</sup>	$10.84 \pm 2.35$ <sup>a</sup>	<0.001***
6 months postoperative	$9.84 \pm 3.35$ <sup>b</sup>	$10.38 \pm 4.35$ <sup>ab</sup>	0.002**
Paired t-test (p-value)	<0.001***	<0.001***	

\*, \*\*, \*\*\*, significant at  $p < 0.05$ ,  $< 0.01$ ,  $< 0.001$ . Intragroup comparison using repeated measures ANOVA. a,b means followed by different letters are significantly different according to DMRTs.

The bone density was significantly increased from an average ( $\pm$ SD) of  $547.43 \pm 32.79 \text{ HU}$  immediate postoperative to an average of  $898.71 \pm 45.8 \text{ HU}$  six months postoperative ( $p < 0.001$ ). The ISQ was significantly increased from intraoperative ( $61.79 \pm 1.87$ ) to six months postoperative ( $79.46 \pm 2.35$ ) ( $p < 0.001$ ). Table(3) The duration of surgical procedure ranged between a minimum of 35 minutes to a maximum of 55 minutes with an average time of surgery ( $\pm$ SD) of  $44.86 \pm 6.62$ .

**Table (3)** Bone density and implant stability Quotient intraoperative and six months postoperatively

Timepoint	Bone density (HU)	
	Mean	SD
Immediate postoperative	547.43	32.79
Six months postoperative	898.71	45.8
Paired t-test	<0.001***	
ISQ		
Intraoperative	61.79	1.87
Six months postoperative	79.46	2.35
Paired t-test	<0.001***	

\*, \*\*, \*\*\*, significant at  $p < 0.05$ ,  $< 0.01$ ,  $< 0.001$ , ns.  
Intragroup comparison using paired samples t-test

## 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<sup>10</sup>. Sinus floor elevation is a well-established surgical technique assisting implant insertion and prosthetic rehabilitation in an atrophying posterior maxilla<sup>11</sup>. In recent advancements in sinus augmentation, 3D-printed surgical guides and piezoelectric surgery are used<sup>12</sup>.

Zaniol et al.<sup>13</sup> 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<sup>14</sup>.

In the present trial, a stereolithographic surgical guide was created preoperatively using the CBCT of the patient and diagnostic cast, considering 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 4.63 millimetres. This agreed with Nedir et al.<sup>15</sup>, 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 84m<sup>2</sup>/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<sup>16</sup>.



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.<sup>13</sup>.

The average ISQ immediately following implant placement and six months postoperatively was ( $\pm$ SD) 61.79 $\pm$ 1.87 and 79.46 $\pm$ 2.35 respectively, revealing a significantly increased ISQ six months postoperative compared to immediate postoperative ISQ ( $P < 0.001$ ). Jelušić et al.<sup>17</sup> reported similar outcomes. Regarding vertical bone height gain the bone gain at 6 months postoperative buccal, and 6 months postoperative palatal recorded an average of 9.84 $\pm$ 3.35, and 10.38 $\pm$ 4.35; respectively. Similar to finding obtained by Arora et al.<sup>18</sup>, who reported a mean vertical bone height gain of 11.23  $\pm$  1.25 mm with a range of (9.5 - 14.8 mm).

The bone density was significantly increased from an average ( $\pm$ SD) of 547.43 $\pm$ 32.79HU immediate postoperative to an average of 898.71 $\pm$ 45.8HU six months postoperative ( $p < 0.001$ ). Close results were obtained by Fouad et al.<sup>2</sup>.

The duration of surgical procedures was recorded in minutes. The mean duration of surgical procedure (minutes) was 44.86 $\pm$ 6.62 minutes with a range between 35 to 55 minutes. Continuing in daily activities, opening the mouth, eating, and speaking was reported, with a minor limitation in swallowing. Procedure chairside duration was reduced, as well as trauma, duration of treatment, and morbidity, with increased patient comfort.

In our study, MSV recorded a difference between time points that was highly significant. Immediate postoperative showed a significant decrease by 6.54% from the preoperative. Moreover, 6 months postoperative showed a 5.88% significant decrease from preoperative ( $p < 0.001$ ). No significant difference was reported between MSV immediately postoperative and 6 months

postoperatively. Schriber et al.<sup>19</sup> evaluated the MS volumetric alteration after tooth extraction utilizing a customized software program, reporting a non-significant variation ( $p > 0.05$ ) between the MSV of dentulous and edentulous patients.

#### **Limitations:**

The large volume of the surgical guides and the complexity of their fabrication technique were major drawback. During study time, we cannot interpret whether more changes occurred for graft material and subsequently volumetric changes for the MS. 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 sinus volume reduction, bone density, and 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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## التحليل النوعي للجيب الفكي العلوي بعد إجراء رفع الجيب الجانبي الموجه مع وضع الزرع في وقت واحد

احمد محمد زويل\* ، محسن فوزى ابو الحسن ، عبد العزيز بيومي عبد الله ، محمد محجوب العشماوى ،  
عرفه جاد الله ابراهيم

1. قسم جراحة الفم والوجه والفكين. كلية طب الأسنان. جامعة الأزهرينين. أسيوط. مصر  
\* البريد الإلكتروني: AHMEDZEWAIL871@GMAIL.COM

### الملخص :

**الهدف:** تقييم تقنية رفع الجيوب الأنفية الجانبية باستخدام دليل جراحي مطبوع ثلاثي الأبعاد مع وضع الزرع في وقت واحد.

**المواد والاساليب:** باستخدام التصوير المقطعي المحوسب بالشعاع المخروطي قبل الجراحة (CBCT) وصورة دقيقة للأسنان. تم إنشاء دليل جراحي. تم إجراء رفع الجيب الجانبي باستخدام دليل جراحي مطبوع ثلاثي الأبعاد لقطع عظم النافذة الجانبية ووضع الزرع. تم الحصول على CBCT وتم قياس حجم الجيب الفكي العلوي (MSV) قبل الجراحة، مباشرة بعد العمل الجراحي. وبعد 6 أشهر. تم أيضًا تقييم ثبات الغرسة (ISQ) باستخدام OSSTELL® فورًا بعد العملية الجراحية وبعد 6 أشهر من العملية الجراحية.

**النتائج:** ظهرت MSV الفورية بعد العملية الجراحية انخفاضًا ملحوظًا مقارنة بما قبل الجراحة. وعلاوة على ذلك. أظهرت 6 أشهر بعد العملية الجراحية انخفاضًا ملحوظًا من فترة ما قبل الجراحة ( $P < 0.001$ ). أظهر الشدق زيادة عظمية أكبر بكثير من الحنكية مباشرة وبعد 6 أشهر بعد العملية الجراحية ( $P < 0.05$ ). تم الإبلاغ عن زيادة ملحوظة في كثافة العظام وISQ بعد ستة أشهر من العمل الجراحي مقارنةً بكثافة العظام بعد العملية الجراحية المباشرة ( $P < 0.001$ ). (ISQ)

**الخلاصة:** يوفر الارتفاع الجانبي لأرضية مرض التصلب العصبي المتعدد باستخدام دليل جراحي مطبوع ثلاثي الأبعاد مع وضع زرع متزامن عملية أسرع ويضمن نتائج يمكن التنبؤ بها. مع الحفاظ الفائق على حجم الجيوب الأنفية وكثافة العظام وISQ

**الكلمات المفتاحية:** جيب الفكي العلوي. رفع الجيب الجانبي الموجه. وضع الزرعات المتزامنة. جراحة البيزو. ISQ. زراعة الأسنان