

Guided Lateral Sinus Augmentation in the Edentulous Maxilla: A Stackable Surgical Guide Protocol: A Case Report

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ABSTRACT

The presented case report showcases the implementation of a digital workflow for a lateral approach sinus augmentation procedure using a stackable surgical guide (SSG). The integration of digital technologies in implant dentistry has revolutionized treatment planning and execution, leading to improved accuracy and efficiency in treatment workflows. This report shows a step-by-step digital workflow utilized in a sinus augmentation procedure for a future implant placement, highlighting the benefits of using a stackable guide system. Through the use of cone-beam computed tomography (CBCT), digital planning software, and computer-aided design and manufacturing (CAD/CAM), precise sinus augmentation with bone grafting placement was achieved, resulting in a successful outcome.

Keywords: Digital workflow; Stackable guide; Lateral approach; Sinus lift; Digital dental technique

INTRODUCTION

The lateral approach sinus lift procedure (LASLP) is a well-established technique for maxillary sinus floor augmentation to enable successful implant placement in the posterior maxilla [1]. Achieving precise and predictable outcomes can be challenging due to the anatomical complexity and variations in the maxillary sinus especially in edentulous patients. Recently, digital workflows and advanced surgical guides have emerged as promising tools to enhance accuracy and efficiency in different dental procedures [2,3]. Further advancements in digital workflows and surgical guides have provided dentists with powerful tools to enhance the execution treatment in different dental procedures, including the lateral approach sinus lift. Integrating digital planning, virtual simulations, and custom-designed stackable surgical guides, dental professionals can achieve a precise implant placement, predictable outcomes, and improved patient satisfaction [4-6].

Several treatment options have been proposed for rehabilitation of the severely atrophic posterior maxilla, including transcrestal (closed) sinus elevation, short implants, tilted implants, pterygoid implants, and implant-assisted removable complete dentures. These alternatives may be particularly beneficial in elderly or medically compromised patients because they can reduce surgical morbidity and treatment complexity. However, when residual bone height is severely limited and substantial vertical bone augmentation is required, the lateral window sinus augmentation technique remains a predictable and widely accepted treatment approach. In the present case, the lateral window approach was selected because of the limited residual alveolar bone height and the need to achieve sufficient bone volume for future implant rehabilitation.

By converting digital images into virtual models, clinicians can perform detailed preoperative planning, simulate the surgical procedure, and assess potential complications in a controlled digital environment [7]. For example in sinus augmentation procedure the most common complication during sinus floor elevation is a membrane perforation and the risk of perforation is increased with a lateral window of inadequate size and accurate position of implant placement based on prosthetically driven implant placement, resulted in a difficult reflection of the sinus floor membrane and improper implant placement [8-12]. The use of a printed surgical guide reduced potential complications during sinus floor elevation, so enhanced accurately and safety of implant placement [13].

A crucial component of the digital workflow for lateral approach sinus lift procedures is a stackable guide system (SGS). These guides are custom-designed based on the virtual surgical plan and fabricated using computer-aided design and computer-aided manufacturing (CAD/ CAM) technologies. The (SGS) consists of multiple guide parts that enable a stepwise approach during the surgical procedure, ensuring optimal precision and control of the future implant placement [10].

This approach provides a guided pathway for osteotomy, sinus membrane elevation, graft and implant placement. The stackable nature of the guides allows a gradual and controlled progression, reducing the risk of complications such as perforations or excessive membrane tearing [11]. Moreover, the stackable design facilitates easy adaptation to different sinus configurations and simplifies the surgical process, resulting in reduced surgical time, complications, and increased efficiency [12,13].

This case report aims to contribute to the growing body of evidence by presenting a detailed account of a successful lateral approach sinus augmentation procedure using these innovative digital techniques. The outcomes of this case report will provide valuable insights into the effectiveness and feasibility of the digital

workflow and (SGS), paving the way for further research and wider adoption of these advancements in oral and maxillofacial surgery.

CASE PRESENTATION

A 52-year-old female with missing maxillary teeth presented for implant rehabilitation. A comprehensive clinical and radiographic evaluation determined that a lateral approach sinus lift was necessary to achieve adequate bone volume for implant placement. To enhance precision and predictability, a digital workflow was chosen, incorporating cone-beam computed tomography (CBCT) imaging and digital planning for the fabrication of a stackable surgical guide (SSG). High-resolution CBCT scans were obtained to evaluate the maxillary sinus anatomy and assess bone quality and quantity. The scans were analyzed using digital planning software to facilitate accurate three-dimensional visualization of the patient's anatomy, enabling virtual implant placement and augmentation of the sinus floor. The prosthetically driven implant positions were determined based on the available bone quality and quantity, as well as the patient's restorative needs. **Figure 1** demonstrates the initial step of the procedure, with full-thickness mucoperiosteal flap elevation exposing the lateral wall of the maxillary sinus prior to sinus augmentation.

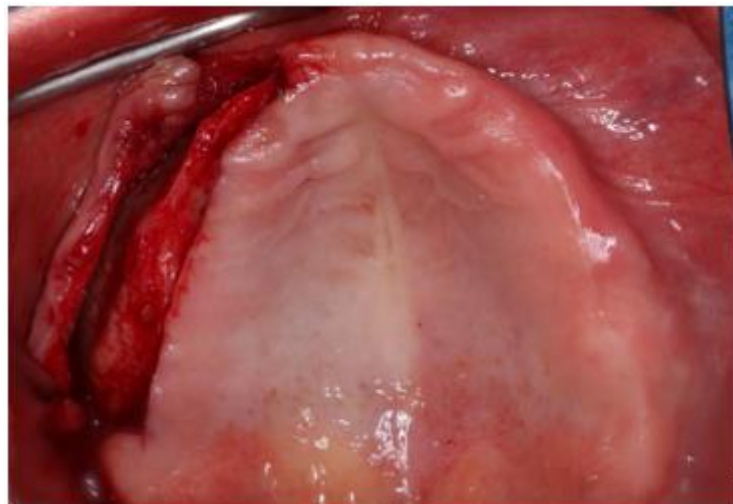


Figure 1: Full-thickness mucoperiosteal flap elevation exposing the lateral wall of the maxillary sinus prior to sinus augmentation.

To further enhance accuracy, the patient's maxillary complete denture was scanned using a 3Shape intraoral scanner, creating a base for palatal support during the procedure. The SSG design involved two components: a base for palatal support, duplicated from the patient's denture, and a guide for the lateral sinus window, which could be securely attached to the base. **Figure 2** illustrates the verification of the prosthetically driven plan with the placement of a tooth-supported surgical guide in situ, confirming occlusal alignment. The guides were designed to be precisely positioned and secured during surgery, ensuring stability and accuracy. The design of the guides was carried out in digital planning software (Meshmixer), and the finalized stackable guides were exported as STL files. **Figure 9A** shows the digital design of a stackable surgical guide generated in Meshmixer, illustrating the prosthetically driven workflow for lateral approach sinus augmentation. **Figure 9B** presents a 3D digital rendering from Meshmixer demonstrating the design phase of a stackable surgical guide for a lateral approach sinus augmentation, showcasing anatomical alignment and guide components in a clinical case report

workflow. **Figure 9C** depicts the prosthetically driven digital design of a stackable surgical guide generated in Meshmixer. **Figure 9** illustrate the digital design phase of the stackable surgical guide, showcasing the prosthetically driven workflow and anatomical alignment. These guides were printed using biocompatible materials through computer-aided design and manufacturing (CAD/CAM) technology, ensuring both accuracy and sterility.



Figure 2: Verification of the prosthetically driven plan with the placement of a tooth-supported surgical guide in situ, confirming occlusal alignment.

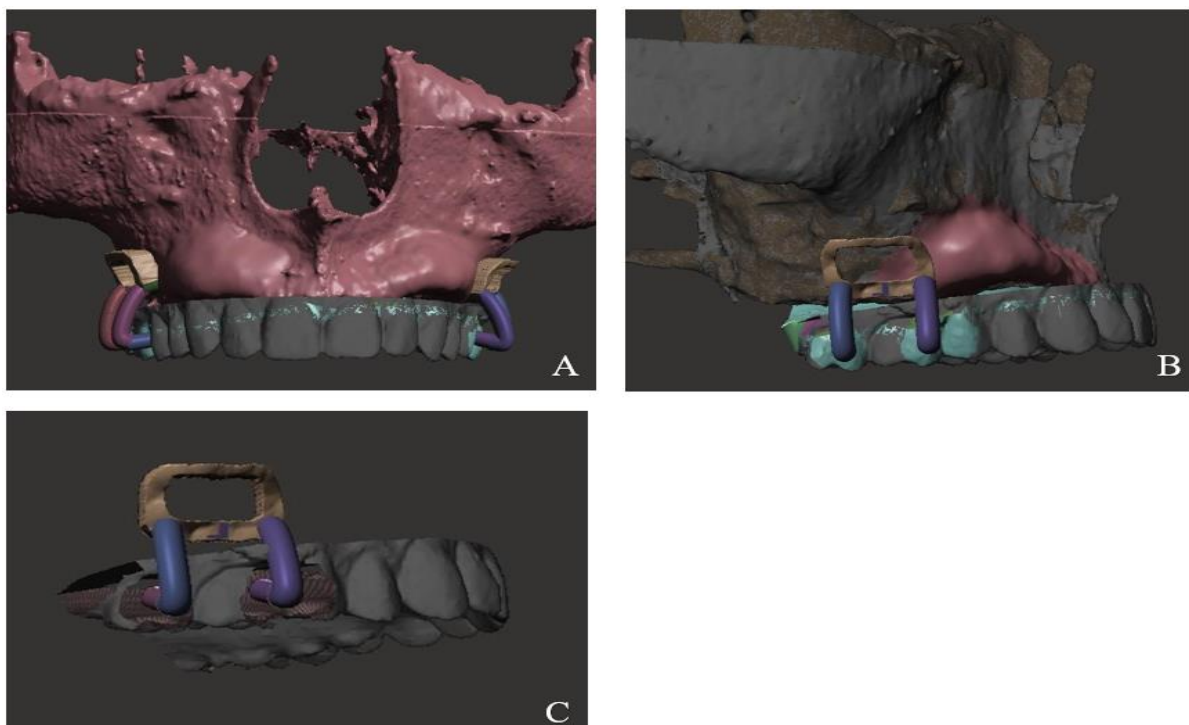


Figure 9A: Digital design of a stackable surgical guide generated in Meshmixer, illustrating the prosthetically driven workflow for lateral approach sinus augmentation. **9B:** A 3D digital rendering from Meshmixer demonstrates the design phase of a stackable surgical guide for a lateral approach sinus augmentation, showcasing anatomical alignment and guide components in a clinical case report workflow. **9C:** Prosthetically driven digital design of a stackable surgical guide generated in Meshmixer.

During the surgical procedure, the stackable guides facilitated precise osteotomy creation and accurate lifting and grafting of the sinus membrane. **Figure 3** shows the intraoperative view of the stackable surgical guide positioned over the maxillary arch, facilitating precise lateral window preparation and osteotomy design for sinus augmentation. Following flap elevation, the lateral wall of the maxillary sinus was outlined, as illustrated in **Figure 4**. In **Figure 5**, the staged lateral sinus augmentation demonstrates a well-defined lateral approach sinus window with intact Schneiderian membrane protection and adequate hemostasis prior to membrane elevation and graft placement. Grafting material was placed 40% xenograft (Bioss; Geistlich Pharma Inc), 40% allograft (Puros Cortical; RTI Biologics, Inc), and 20% autogenous graft material in the sinus as shown in **Figure 6**, and a perforated titanium mesh was secured over the lateral window to stabilize the graft, as demonstrated in **Figure 7**. Finally, the surgical site was closed using tension-free interrupted sutures, achieving primary closure using polytetrafluoroethylene (Gore-Tex; W.L. Gore & Associates) as shown in **Figure 8**.

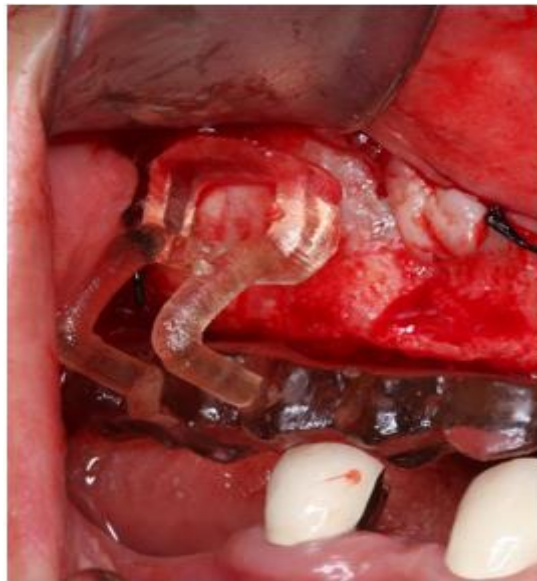


Figure 3: Intraoperative view of the stackable surgical guide positioned over the maxillary arch, facilitating precise lateral window preparation and osteotomy design for sinus augmentation.



Figure 4: Clinical intraoral view of the posterior maxilla following full-thickness mucoperiosteal flap elevation and a lateral window is outlined.



Figure 5: Intraoperative view of a staged lateral sinus augmentation showing a flap with a well-defined lateral approach sinus window outlined in the maxillary sinus wall, intact Schneiderian membrane protection, and adequate hemostasis prior to membrane elevation and graft placement.



Figure 6: Intraoperative view of a staged lateral sinus augmentation showing a well-defined lateral antrostomy window outlined in the maxillary sinus wall, with graft material placed inside.



Figure 7: Intraoral maxillary view of a staged lateral sinus augmentation with perforated titanium mesh secured over the lateral window to stabilize the graft.

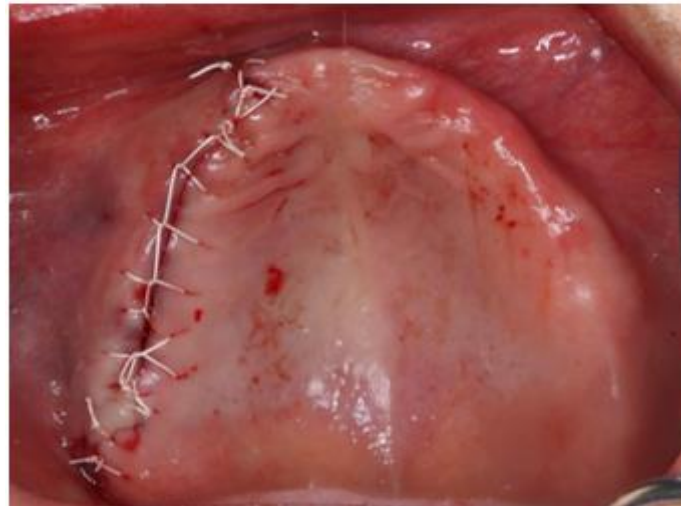


Figure 8: Post-operative maxillary view primary closure interrupted suture of site with tension free.

The digital workflow was critical to the success of the procedure, integrating advanced imaging and planning technologies with precise surgical execution. **Figure 9** provides a superimposed three-dimensional reconstruction of the maxillary sinus and dentition, demonstrating the integration of the stackable surgical guide within the digital workflow for lateral approach sinus augmentation. The workflow design is further illustrated in **Figures 9**, which highlight the 3D-rendered visualization from Meshmixer, showcasing anatomical structures and guide components for precise clinical application. This comprehensive digital workflow enabled precise, prosthetically driven planning and execution of a lateral approach sinus augmentation, demonstrating the effectiveness of integrating digital planning with advanced guide fabrication for implant rehabilitation.

DISCUSSION

The application of a digital workflow using stackable surgical guides in lateral approach sinus augmentation surgeries offers several advantages over traditional techniques [1]. The use of advanced imaging, virtual planning, and 3D printing enhances the accuracy and predictability of the procedure [2,3]. (SSG) minimal surgical complications, and the patient achieved successful implant integration and restoration. A limitation of this case report is the absence of postoperative follow-up radiographs and long-term clinical documentation, which precluded objective assessment of implant integration, bone healing, and functional outcomes. However, challenges such as guide stability and learning curve associated with the digital workflow should be considered. The advantage of (CBCT) imaging is the ability to obtain detailed three-dimensional information about the maxillary sinus anatomy and bone quality [6]. This information is crucial for determining the feasibility of implant placement and selecting appropriate implant sizes and lengths [8]. By visualizing the sinus anatomy accurately, clinicians can assess the available bone volume and quality, thereby reducing the risk of complications during surgery [7,13].

Digital planning software plays a vital role in virtual treatment planning, allowing clinicians to visualize and plan the entire procedure before executing it. This software enables the clinician to assess the relationship between the implant position and adjacent anatomical structures, ensuring optimal placement. By virtually visualizing the surgery, potential challenges can be identified and addressed in advance, leading to more precise implant placement and improved treatment outcomes.

The utilization of CAD/CAM technology in the design and fabrication of surgical guides offers several advantages [1]. The customized printed surgical guides, designed based on the virtual treatment plan, provide precise guidance for osteotomy preparation and implant placement. The stackable design of the guides allows for sequential drilling and implant insertion, reducing the need for guide removal and repositioning. This streamlined process reduces surgical time and improves accuracy, minimizing the risk of errors. The positive outcomes observed in this case report are in line with previous studies that have demonstrated the benefits of digital workflows in implant dentistry. The accurate implant placement and restoration achieved through the digital workflow contribute to improved aesthetic and functional outcomes. Patients experience enhanced chewing efficiency and overall satisfaction with the restoration. Moreover, the use of digital technologies allows for a more predictable and efficient treatment process, reducing the potential for complications and improving patient safety. The present report focuses on the technical aspects of guided sinus augmentation rather than long-term implant or prosthetic outcomes. While this case report highlights the advantages of a digital workflow with a stackable surgical guide (SSG) in a lateral approach sinus lift procedure, research and clinical studies are necessary to validate these findings and expanded applications.

CONCLUSION

This case report highlights the advantages of using SSG and implementing a digital workflow in a lateral approach sinus augmentation procedure. The integration of CBCT imaging, digital planning software, and CAD/CAM technology enables precise treatment planning, accurate implant placement, minimum invasive procedure, and improved patient outcomes.

CONFLICT OF INTEREST STATEMENT

The authors disclosed no conflict of interest.

Informed Consent

Written informed consent was obtained from the patient for publication of this case report and the accompanying clinical images.

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Author Approval and Responsibility Statement

All authors have read and approved the final version of the manuscript. The corresponding author had full access to all of the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis.

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The authors have no acknowledgments to declare.

Data Availability Statement

The authors confirm that the data supporting the findings of this study are available within the article and/or its supplementary materials.

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