Enhancing Precision and Outcomes in Sinus Lift Surgery: The Role of Static Surgical Guides for the lateral window approach in Sinus Augmentation

Abstract

Aim
To evaluate the clinical efficacy and accuracy of using static surgical guides in lateral window sinus lift procedures for dental implant placement in patients with severely resorbed posterior maxilla.

Materials and Methods
This prospective case series was conducted at Saveetha Dental College and Hospital, Chennai, from October 2024 to April 2025. Three patients (2 females, 1 male; mean age 48.3 ± 6.2 years) with posterior maxillary partial edentulism and residual bone height less than 5 mm were subjected to sinus augmentation using patient-specific static surgical guides. Preoperative planning involved cone-beam computed tomography (CBCT) and intraoral digital scanning, which were merged using ExoPlan software to design and fabricate the surgical guides. Lateral window osteotomies were performed using round burs under the guidance of the printed templates. Sinus membrane elevation, bone grafting with xenograft (Bio-Oss, Geistlich, Switzerland), and membrane placement (Creos, Nobel Biocare, Switzerland) were performed in all cases. Implant placement was either simultaneous or delayed based on residual bone height.

Discussion
Static surgical guides enabled precise transfer of the virtual surgical plan into the clinical setting, allowing accurate osteotomy window placement while avoiding critical anatomical structures such as the Schneiderian membrane, antral artery, and sinus septa. Membrane elevation was successfully completed without perforation in all three cases. The guided approach enhanced graft containment, minimized complications, and facilitated accurate implant positioning with high primary stability. The digital workflow also contributed to improved surgical efficiency, reduced operative stress, and positive patient-reported outcomes. These findings align with existing literature supporting the benefits of guided surgery in complex maxillary procedures.

Conclusion
The use of static surgical guides in lateral window sinus lift surgeries offers a reliable, accurate, and minimally invasive approach for augmenting severely resorbed posterior maxillae. This technique reduces the risk of complications, improves graft placement, and supports predictable implant outcomes. Despite the limited sample size, results suggest that digital-guided sinus augmentation is a promising modality for complex implant cases and warrants further investigation through larger-scale studies.

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Keywords

Static surgical guide, sinus lift, lateral window osteotomy, maxillary sinus augmentation, CBCT, guided implant surgery, digital workflow, Bio-Oss, posterior maxilla.

INTRODUCTION

Dental implantology has become a fundamental aspect of contemporary restorative dentistry, providing patients with a reliable and aesthetically satisfying solution for tooth replacement (1). Nevertheless, the success of dental implants heavily depends on the presence of adequate bone volume at the intended implant site. In the posterior maxilla, insufficient bone height is a common issue, primarily due to the natural pneumatization of the maxillary sinus (2). This process involves the expansion of the sinus cavity, which results in a decrease in alveolar bone height. To overcome this challenge, in 1980 Tatum introduced sinus lift surgery, or sinus augmentation, as a standard preparatory procedure to gain bone height in the posterior maxilla for implant placement (3). This surgical technique entails lifting the Schneiderian membrane (the mucosal lining of the maxillary sinus) and inserting bone graft or bone substitute materials into the elevated space to increase vertical bone height, thereby facilitating the successful placement of dental implants (4).

Despite its critical role in implant dentistry, sinus lift surgery is a complex and technically demanding procedure (5). It carries inherent risks, such as perforation of the sinus membrane, improper graft placement, and suboptimal implant positioning, which can compromise the long-term success of the implant (6). Additionally, the procedure requires a high degree of precision to ensure that the graft material is adequately contained and that the implant is placed in the correct three-dimensional position for functional and aesthetic outcomes (7). Furthermore, presence of the antral artery in the region where the sinus window has to be created adds to the risks involved in the procedure (8). Even the occurrence of a sinus septa can complicate the lateral window approach in sinus lift procedure (9). These challenges have driven the development of innovative tools and techniques to enhance the predictability and safety of sinus lift surgery.

One such advancement is the integration of static surgical guides into the sinus lift and implant placement process (10). Static surgical guides are custom-made devices fabricated using digital technologies such as cone-beam computed tomography (CBCT) and computer-aided design/computer-aided manufacturing (CAD/CAM) (11). These guides are designed based on the anatomical data of the patient, allowing for precise planning of the osteotomy, sinus lift, and implant placement (12). By providing a physical template that aligns with the anatomy of the patient, static guides enable clinicians to execute the surgical plan with a high degree of accuracy, reducing the risk of errors and complications (13).

The use of static guides in sinus lift surgery offers several potential advantages (14). First, it enhances the precision of the osteotomy and sinus membrane elevation, minimizing the risk of membrane perforation and ensuring optimal graft placement. Second, it allows for the accurate positioning of the sinus window to avoid the antral artery or a septa if it is present in that region (8,9). Third, it reduces surgical time and improves patient comfort by streamlining the procedure (13). Furthermore, the use of static guides can be particularly beneficial in complex cases, such as those involving limited bone volume or challenging anatomical variations (12,14).

MATERIALS AND METHODS

Study Design and Patient Selection

The study was conducted as a prospective case series at the Department of Implantology, Saveetha Dental College and Hospital, Chennai, between October 2024 and April 2025. Three consecutive patients (2 males, 1 female; mean age 48.3±6.2 years) with posterior maxillary partial edentulism and residual bone height <5mm were enrolled. Inclusion criteria required patients to be aged 30-65 years, have good systemic and oral health, and demonstrate 2-5mm of residual bone height on CBCT. Exclusion criteria eliminated those with active sinus pathology, uncontrolled systemic diseases (e.g., diabetes with HbA1c >7%), heavy smoking (>10 cigarettes/day), previous sinus surgery, or pregnancy. Ethical approval was obtained from the Institutional Human Ethical Committee (Approval number: SRB/SDC/PhD/IMPLANT-2003/22/017), and all participants provided written informed consent in accordance with the Declaration of Helsinki.

Preoperative Planning and Guide Fabrication

Comprehensive preoperative planning involved CBCT scans (CS 9600, Carestream, USA) and digital impressions (TRIOS 5, 3Shape, Denmark). The DICOM and STL files were merged in ExoPlan software to create 3D surgical models, enabling precise measurement of residual bone dimensions and sinus anatomy. Custom static guides were digitally designed with full-arch stabilization, precise osteotomy window positioning, and instrumentation sleeves, then 3D printed using Formlabs Dental SG resin. Post-processing included isopropyl alcohol washing, UV curing, and ethylene oxide sterilization to ensure biocompatibility and accuracy (±50µm).

Surgical Protocol

All procedures were performed by a single surgeon under strict aseptic conditions. After preoperative antibiotics and local anesthesia, the mucoperiosteal flap was elevated and the sterilized guide was positioned. A guided lateral window osteotomy was performed using a 2.3mm round bur with copious

irrigation, followed by careful sinus membrane elevation. Following Valsalva maneuver confirmation of membrane integrity, Bio-Oss graft material was placed in layers. Primary closure was achieved with 3-0 silk sutures.

Postoperative Evaluation

Patients received immediate postoperative CBCT scans and were prescribed antibiotics, analgesics, and chlorhexidine mouthrinse. Radiographic evaluations at 6 months analyzed graft volume maintenance, absence of infection, and no membrane perforation.

Case 1

A 56-year-old female patient reported to the Department of Implantology, Saveetha Dental College, Chennai with the chief complaint of missing teeth in the upper posterior maxilla. Radiographic examination using Cone Beam Computed Tomography (CBCT) revealed severely resorbed alveolar bone in the region of teeth 25 and 26, with a residual bone height of less than 4 mm beneath the maxillary sinus, thereby indicating the need for a direct (lateral window) sinus lift prior to implant placement.

A digital workflow was followed for treatment planning. An intraoral scan was performed and merged with the CBCT data using ExoPlan software. The lateral window design was digitally planned, and a static surgical guide was fabricated with a dedicated window to indicate the precise outline for lateral wall access to the maxillary sinus. This ensured accurate localization of the osteotomy site and minimized the risk of damaging vital anatomical structures.

On the day of surgery, local anesthesia was administered, and the static surgical guide was positioned and verified for accurate fit. A full-thickness mucoperiosteal flap was then elevated to expose the lateral wall of the maxilla. The surgical guide was repositioned to mark

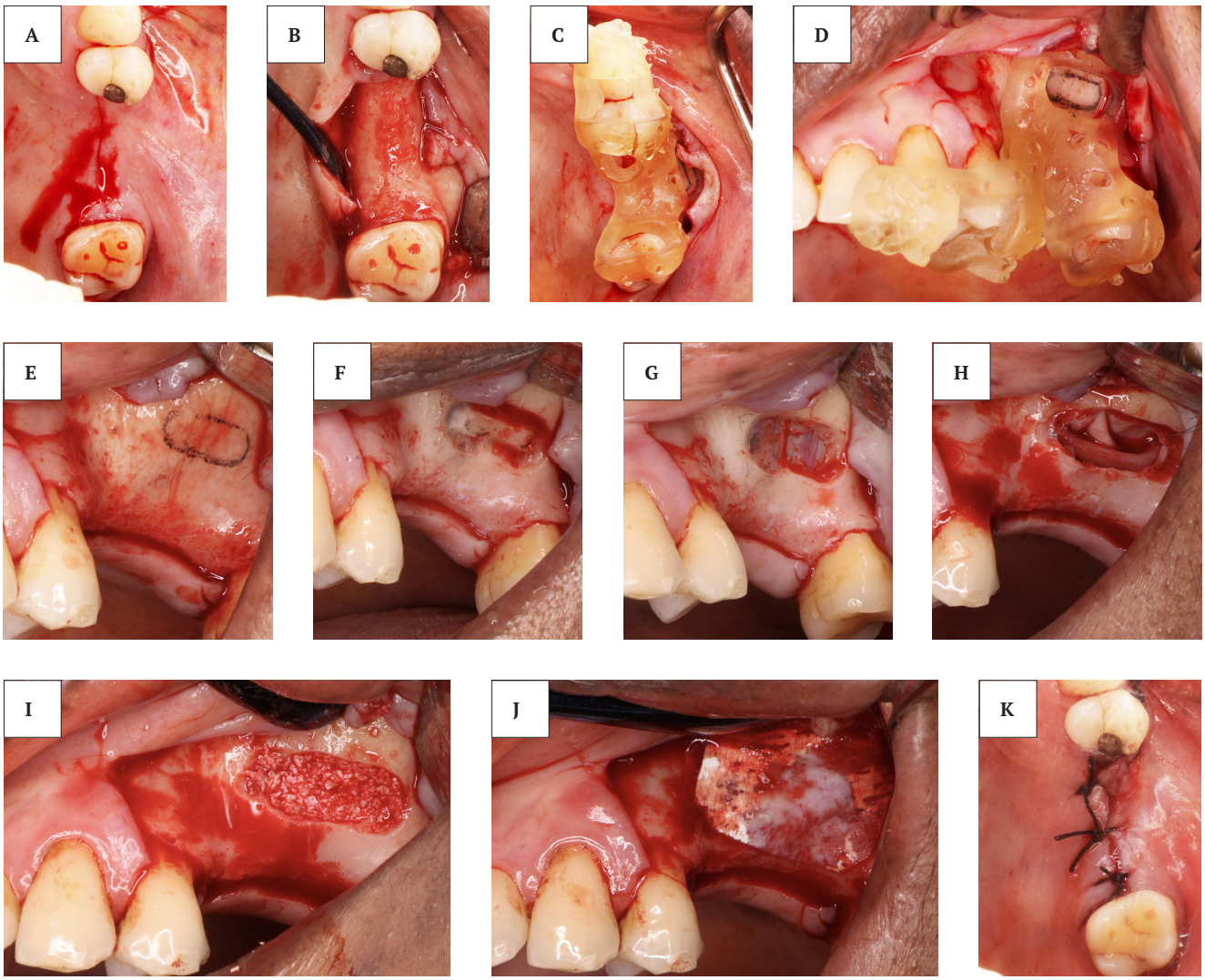

Fig. 1 (**A**) Incision, (**B**) Flap Elevation, (**C**) Static guide seating, (**D**) Lateral window marking,(**E**) Marking window, (**F**) Window preparation, (**G**) Lateral window removal, (**H**) Sinus membrane elevation, (**I**) Grafting, (**J**) Membrane Placement, (**K**) Suturing

the precise borders of the osteotomy window through the pre-designed lateral access slot. Osteotomy of the lateral wall was performed accordingly using a round burr, providing access to the maxillary sinus. The Schneiderian membrane was carefully elevated without perforation, and a xenograft bone substitute (*Bio-Oss, Geistlich, Switzerland*) was packed into the sinus cavity followed by a membrane (*Creos, Nobel Biocare, Kloten, Switzerland*) to augment the subantral space and promote future implant stability.
Following graft placement, the site was closed with non resorbable sutures. (Figure 1) In this case, due to limited residual bone height, implant placement was deferred and planned for after the healing phase. The patient was prescribed antibiotics and analgesics and instructed on postoperative care. Healing was uneventful, and follow-up radiograph after six months showed sufficient bone formation in the grafted site, making it suitable for implant placement.

Case 2

A 63-year-old male patient presented to the Department of Implantology with the chief complaint of missing teeth in the upper left posterior maxilla. Clinical and radiographic examination, including Cone Beam Computed Tomography (CBCT), revealed significant pneumatization of the maxillary sinus and advanced resorption of the alveolar ridge in the region corresponding to teeth 26 and 27. The residual bone height beneath the sinus floor was measured to be approximately 3–4 mm, which was insufficient for conventional implant placement, thus necessitating a direct (lateral window) sinus augmentation procedure. A fully digital workflow was adopted for treatment planning. Intraoral scans were obtained and integrated with the CBCT data using exoplan software. This integration allowed for the precise virtual design of the lateral sinus window while avoiding critical anatomical structures, particularly the posterior superior alveolar

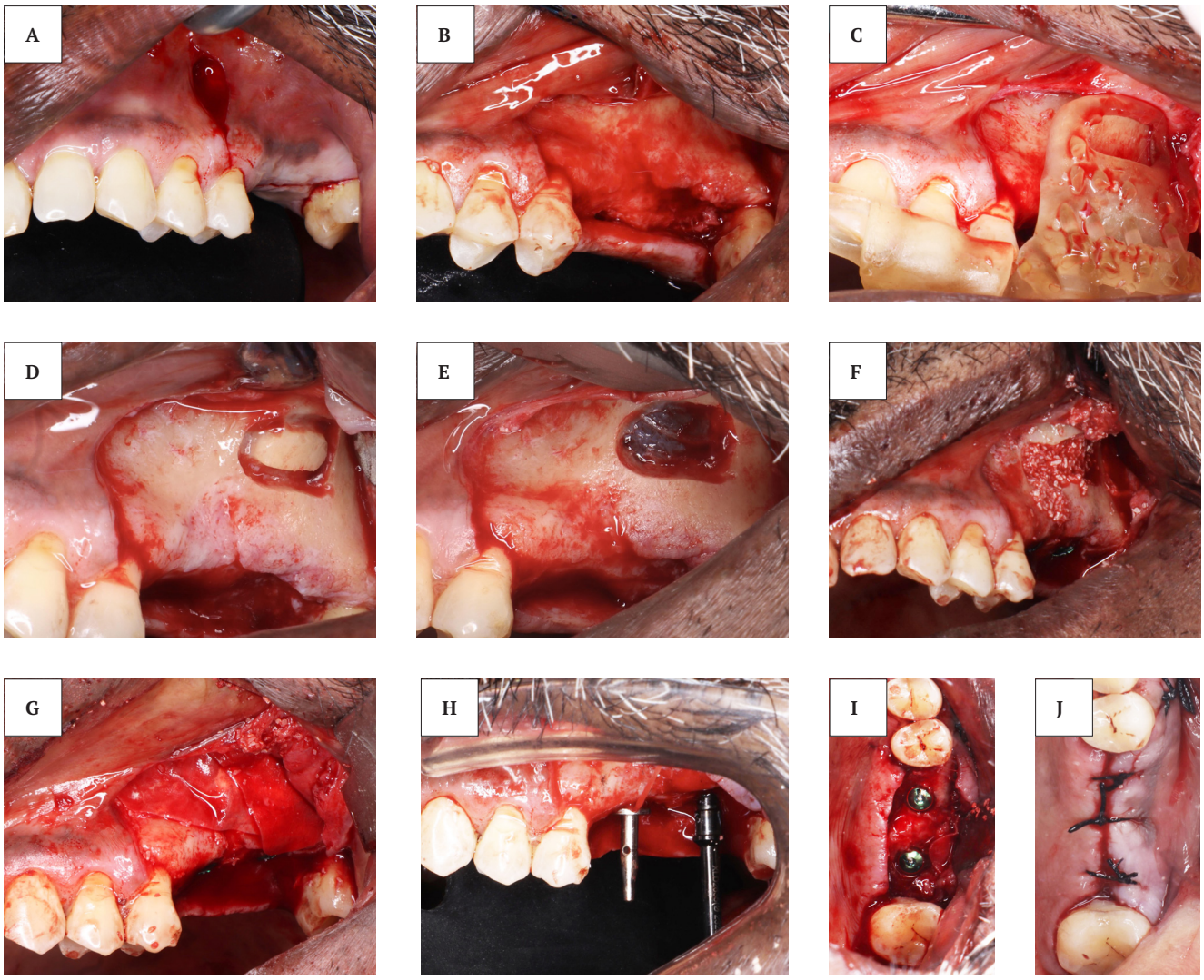

Fig. 2 (**A**) Incision, (**B**) Flap Elevation, (**C**) Static guide seating and window marking, (**D**) Lateral window preparation, (**E**) Lateral window removal, (**F**) Grafting, (**G**) Membrane Placement, (**H**) Position indicating device, (**I**) Implant Placement wrt 16, 17, (**J**) Suturing

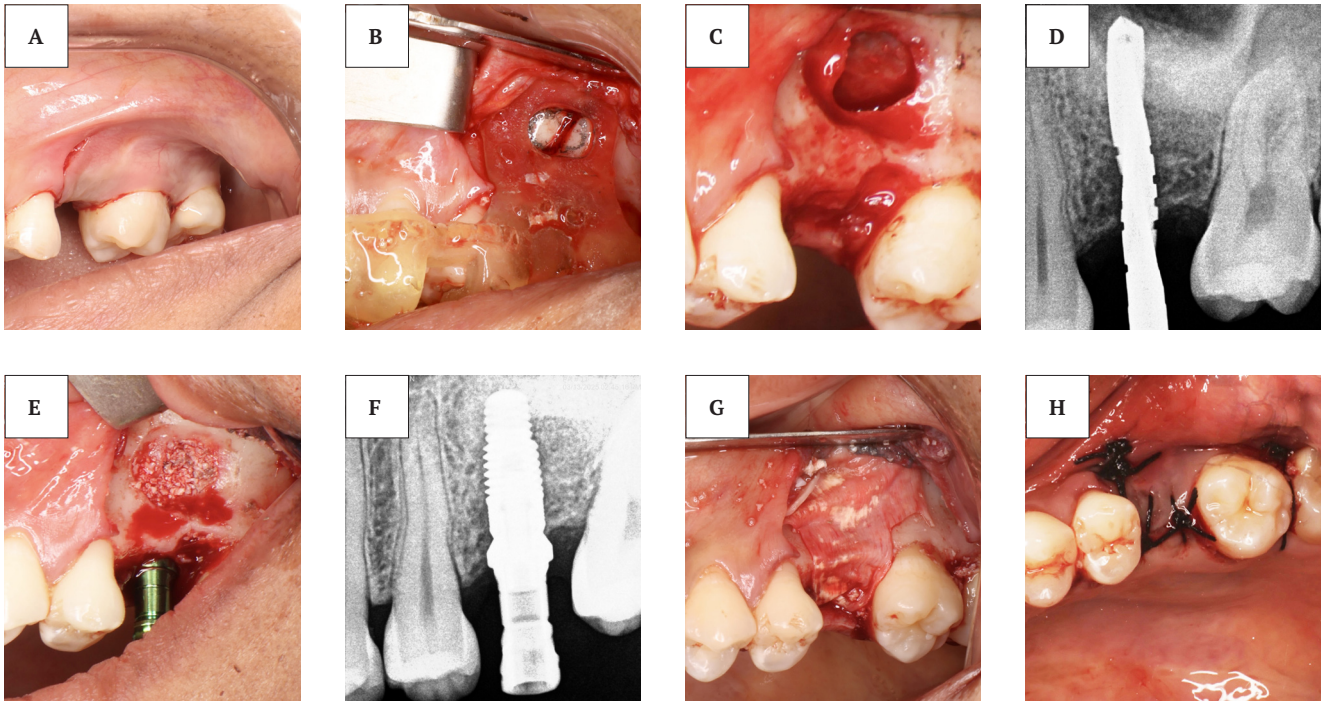

Fig. 3 (**A**) Incision; (**B**) Static guide placement and lateral window marking; (**C**) Lateral window preparation and removal; (**D**) PID Radiograph; (**E**) Bone graft and implant placement; (**F**) Implant placement radiograph; (**G**) Membrane placement; (**H**) Suturing

artery. Based on this digital plan, a static surgical guide was fabricated. The guide included a lateral window outline, enabling accurate and safe preparation of the bony window during the surgical procedure.

On the day of surgery (Figure 2), local anesthesia was administered, and a full-thickness mucoperiosteal flap was elevated to expose the lateral wall of the maxillary sinus. The static surgical guide was positioned and verified for proper adaptation. The outline of the lateral window was transferred to the bone through the guide. A round bur was then used to perform the osteotomy, facilitating minimally invasive access to the sinus cavity. The Schneiderian membrane was elevated carefully using standard sinus lift instruments, and no membrane perforation was observed.

A xenograft bone substitute (*Bio-Oss, Geistlich, Switzerland*) was used to fill the lifted sinus cavity. A resorbable collagen membrane (*Creos, Nobel Biocare, Kloten, Switzerland*) was then placed to cover the grafted area and maintain space for bone regeneration. Implant osteotomies were prepared in the positions of teeth 26 and 27 using sequential drilling, and two implants each of the dimension 4x10 mm (*Dentium, Seoul, South Korea*) were placed with adequate primary stability. Cover screws were secured, and the surgical site was closed using resorbable sutures. The patient was prescribed a standard postoperative regimen including antibiotics, analgesics, and chlorhexidine mouth rinse. Postoperative healing was uneventful.

At the six-month follow-up, radiographic evaluation confirmed the successful osseointegration of the implants, with no signs of complications. This case illustrates the advantages of a digital approach in complex sinus augmentation procedures, offering enhanced precision, surgical safety, and treatment predictability. The integration of intraoral scanning, CBCT data, and computer-guided planning facilitated a safe and efficient surgical workflow in a highly resorbed maxillary posterior region.

Case 3

A 31-year-old female presented to the Implantology Department with missing teeth in the upper right posterior maxilla. Clinical and radiographic evaluation, including Cone Beam Computed Tomography (CBCT), revealed significant maxillary sinus pneumatization and marked alveolar ridge resorption in the area corresponding to teeth 16. The residual bone height beneath the sinus floor measured approximately 5.6 mm, which was inadequate for conventional implant placement. Therefore, a lateral window sinus augmentation procedure was planned.

A fully digital workflow was utilized for treatment planning. Intraoral scans were combined with CBCT data using ExoPlan software, enabling precise virtual design of the lateral sinus window while avoiding critical anatomical structures such as the posterior superior alveolar artery. Based on this plan, a static surgical guide outlining the lateral window was fabricated to ensure accurate and safe bony window

preparation during surgery.
On the day of the procedure (Figure 3), local anesthesia was administered, and a full-thickness mucoperiosteal flap was reflected to expose the lateral sinus wall. The static guide was positioned and verified for proper fit, and the lateral window outline was transferred to the bone through the guide. A round bur was used to perform the osteotomy, allowing for minimally invasive access to the sinus cavity. The Schneiderian membrane was gently elevated without any perforations.

The sinus cavity was then filled with a xenograft bone substitute (*Bio-Oss, Geistlich, Switzerland*), followed by placement of a resorbable collagen membrane (*Creos, Nobel Biocare, Kloten, Switzerland*) to maintain space for bone regeneration. Implant osteotomies were prepared at the sites of teeth 16, and one implant of dimension 4.1x10 mm (*Zimmer, Warsaw, Indiana, United States*) was inserted with adequate primary stability. Cover screws were placed, and the surgical site was closed with resorbable sutures. (Figure 3) Postoperative care included antibiotics, analgesics, and chlorhexidine mouth rinses. Healing proceeded without complications.

At the six-month follow-up, radiographic assessment confirmed successful osseointegration of the implants, with no signs of adverse events. This case demonstrates how a digital approach in sinus augmentation can enhance precision, safety, and predictability, especially in severely resorbed posterior maxillary regions. The integration of intraoral scanning, CBCT, and computer-guided planning facilitated a smooth and efficient surgical workflow.

RESULTS

Three patients (two males and one female) with an average age of 48.3 ± 6.2 years underwent lateral window sinus lift surgery using static surgical guides. All patients had residual bone heights ranging from 3 to 5.6 mm, confirming the necessity for sinus augmentation. The static surgical guides fit accurately in all cases, facilitating precise transfer of the virtual surgical plan to the clinical setting. This precision allowed for the osteotomy windows to be created exactly as planned, successfully avoiding critical anatomical structures such as the antral artery and sinus septa where applicable. No intraoperative instability or slippage of the guides was observed, ensuring a smooth surgical procedure.

Sinus membrane elevation was achieved without any perforations in all cases, verified intraoperatively through Valsalva maneuver and confirmed on postoperative CBCT scans. Additionally, no complications such as sinus infections, bleeding, or graft displacement occurred during the follow-up period.
Implants were placed simultaneously during sinus augmentation in two patients, both achieving excellent primary stability with insertion torque values greater than 35 Ncm. Follow-up radiographs revealed accurate implant positioning consistent with the surgical plan. In the remaining patient, implants were deferred until six months post-augmentation; subsequent imaging showed sufficient bone height and density to support successful implant placement. No sinus-related symptoms such as congestion or infection were reported during the follow-up period.

DISCUSSION

This study demonstrates that the use of static surgical guides in lateral window sinus lift procedures significantly improves surgical precision and clinical outcomes in patients with severely resorbed posterior maxillae. The integration of CBCT imaging and digital impressions enabled accurate preoperative planning and fabrication of patient-specific guides, which effectively translated the virtual surgical design into the operative field. This level of precision is particularly crucial given the proximity of vital structures like the Schneiderian membrane and posterior superior alveolar artery. The absence of membrane perforations across all cases aligns with prior evidence that guided surgery reduces the risk of this common complication, thereby enhancing the likelihood of successful sinus augmentation.

The ability of static guides to accurately position the osteotomy window allowed for minimal trauma and reduced surgical risk. Careful preoperative identification and avoidance of anatomical variations such as sinus septa contributed to the uneventful surgeries and absence of intraoperative bleeding or postoperative sinus infections. This targeted approach contrasts with traditional freehand techniques, which can be more prone to error and complications. Moreover, the guides facilitated precise graft placement, resulting in stable graft volumes and progressive bone formation, which are key predictors of long-term implant success.

The simultaneous implant placement in two patients without compromising primary stability highlights a further advantage of this approach. Accurate implant osteotomies within the augmented sinus reduce micromotion and promote osseointegration, potentially shortening overall treatment times. For the patient in whom implant placement was delayed, the guided augmentation nonetheless provided sufficient bone volume to allow for predictable implant insertion after healing, demonstrating the versatility and

efficacy of the method.

Patient comfort appeared to benefit from the use of static guides, as evidenced by low postoperative pain scores and uneventful recoveries. Though surgical time was not formally recorded, the streamlined workflow afforded by the guides likely contributed to less operative stress and faster procedures, consistent with findings from previous research. However, the small sample size limits the generalizability of these results. Larger controlled studies are necessary to compare guided and freehand sinus lift techniques and to evaluate long-term implant survival and graft stability.

CONCLUSION

In conclusion, static surgical guides enhance accuracy, safety, and predictability in lateral window sinus lift procedures. This digital approach represents an important advancement in managing posterior maxillary atrophy, improving surgical outcomes and patient experiences in complex implant rehabilitation cases.

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