Sinus floor elevation with the lateral window approach has proven to be an effective treatment modality for vertical bone augmentation in the posterior region of the maxilla. The simultaneous implant placement during the procedure can be achieved if enough remaining bone height is available to obtain implant primary stability. However, the proper identification of the maxillary sinus boundaries for the window demarcation along with membrane protection for simultaneous implant placement can be challenging. This clinical report demonstrates a novel technique for sinus floor augmentation using a 3D modified implant-osseous-membrane surgical template to assist in the lateral window demarcation, membrane stabilization and protection, and guided implant placement in a partially edentulous patient who was eligible for one-stage sinus floor elevation. The surgical procedure for the sinus demarcation is simplified, the membrane stabilization and protection are effective, and the guided implant placement provided a predictable surgical positioning of the implants. Int J Oral Maxillofac Implants 2020;35:1203–1208. doi: 10.11607/jomi.8396

**Keywords:** CAD/CAM, guided implant surgery, guided sinus floor elevation, sinus floor elevation, 3D printing

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Maxillary sinus floor elevation by the lateral window approach was first described by Tatum in 1977 and Boyne and James in 1980. Research and clinical reports over the past 40 years have demonstrated that implant placement in combination with maxillary sinus floor elevation is a predictable treatment method with implant survival rates comparable to the conventional implant placement protocol. Nonetheless, common intraoperative complications associated with the lateral approach sinus elevation include sinus membrane perforation, excessive bleeding, infection, wound dehiscence, and loss of grafting material.

It is essential to avoid aberrant sinus anatomy such as sinus septa and arteries during preparation, since they can present higher rates of intraoperative bleeding and membrane perforation. Therefore, proper and precise design and position of the lateral window are necessary to make the elevation procedure easier and help the clinician to successfully elevate the sinus membrane uneventfully. Also, direct visualization facilitates better condensation of the entire grafted compartment, which is critical for providing part of the primary stability for simultaneous implant placement together with lateral window sinus elevation. Clinical evidence also indicates that simultaneous implant placement with sinus floor elevation is a feasible treatment modality in occasions where a minimal residual alveolar bone height is present, ensuring implant primary stability. However, osteotomy preparation without interfering with the sinus membrane during one-stage sinus floor elevation is technique-sensitive and more challenging compared with a two-stage approach.

The application of digital technology has proven to be an invaluable tool for diagnosis and treatment planning. Data acquired from CBCT scans, digital intraoral scans, and facial scans can be integrated and manipulated using dedicated computer software, offering an interactive interface for clinicians to perform virtual surgical planning prior to the actual surgical procedure. Additionally, the use of 3D printing technology enables the reproduction of patients’ bony anatomy as physical models, along with precise surgical templates and guides. Somji et al used a 3D model prior to sinus surgery to simulate the procedure for improvement of the sinus augmentation technique and outcomes. The fabrication of 3D printed surgical guides to outline the lateral window was first demonstrated by Mandelaris and Rosenfeld. Other authors have modified the technique by effectively utilizing various implant planning software.

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During the sinus floor elevation procedure, the sinus membrane often requires additional attention and delicate management, which has not been addressed in the previous reports. This clinical report outlines a digital workflow to design a 3D printed Implant-Osseous-Membrane Guide (IOMG) for lateral window sinus floor elevation and simultaneous guided implant placement. This multifunctional surgical template can help clinicians outline the sinus window and further assist membrane stabilization and protection. This approach would allow clinicians to perform one-stage sinus floor elevation surgeries more efficiently and precisely while reducing the risk of membrane perforation during the implant osteotomy preparation.

**CASE REPORT AND TECHNIQUE**

**Case Presentation**
A male patient 52 years of age presented at the Harvard School of Dental Medicine School Dental Center. The patient has a history of prostate cancer that has been treated and is currently in remission, with otherwise good overall health. Extraoral examination revealed no signs of loss of vertical dimension of occlusion, nor altered lip support or facial profile. Intraoral examination displayed previous restorative work in adequate condition with good overall oral health, with only localized gingival recession. During intraoral examination, a localized swelling in the vestibule in the region of the maxillary right first and second premolars was visible, and sensitive upon palpation. Periapical radiographs revealed failed endodontic treatment with apical radiolucency, suggestive of chronic periapical abscess, along with the presence of a fiber glass fiber post in the first premolar and a short cast post and core in the second premolar (Fig 1a). A percussion test revealed mild sensitivity, while periodontal probing showed localized deep periodontal pockets in both teeth. Based on the clinical and radiographic findings, the teeth were deemed unrestorable. From the treatment options presented, the patient opted for extraction of the unrestorable maxillary premolars and replacement with two endosseous implants with single implant-supported restorations.

For the implant planning, a full-arch maxillary CBCT was taken at 120 Kv, 5 mA with a voxel size of 0.3 mm (i-CAT, Imaging Sciences International), and exported as digital imaging and communications in medicine (DICOM) data files (Fig 1b). Additionally, maxillary and mandibular digital scans were acquired with an intraoral scanner (iTero Element, iTero), providing a standard tessellation language (STL) set of articulated digital cast.

Due to the extent of the infection and the unfavorable amount of remaining bone height, the type 4C late implant placement and conventional loading protocol was indicated (Fig 1b). Therefore, the patient was scheduled for extraction of the unrestorable dentition followed by a 6-month healing period.

**Implant Planning and Design of Implant-Osseous-Membrane Guide**
After 6 months of healing, a second CBCT was taken using the same parameters for the first diagnostic exam. Additionally, a new intraoral digital scan of the maxillary and mandibular arches was taken. The DICOM data set obtained from the CBCT was imported to dedicated implant planning software (coDiagnostiX, Dental Wings) and segmented according to the necessary field of interest. The STL files obtained before and after extraction were imported to the implant planning software and registered onto the DICOM segmented 3D model using the maxillary teeth as reference (Fig 2). The preextraction intraoral digital scan served as diagnostic tooth arrangement for the future implant position. An evaluation of the cross-sectional sagittal view of the edentulous site revealed a subantral bone height of 5 mm in the second premolar site and 6 to 7 mm in the first premolar site, along with a steep sloped configuration of the sinus floor. Furthermore, the mesial-distal distance of the edentulous site was limited after confirmation with the digital diagnostic tooth arrangement. Based on prosthetic-driven position, reduced-diameter implants were planned for both premolars (Bone Level Tapered NC 3.3 × 10 mm, Straumann). A tooth-supported surgical template was designed, and its STL file was exported. The bone and teeth 3D segmentation were also exported as STL files. All exported files retained their relative coordinate positions, which were

![Fig 1](a) Periapical radiograph of maxillary right premolars showing apical radiolucency and poor root canal fillings. (b) Preoperative cross-sectional CBCT sagittal view of second (left) and first premolars (right).
maintained when importing the files into subsequent computer-aided design (CAD) software.

Both the implant surgical template and the 3D segmentation STL files were imported into free sculpting-based CAD software (Meshmixer, Autodesk). An outline of the access window for external sinus floor elevation was determined on the 3D model image using the transparency tool, revealing the anatomy of the sinus, which allowed for a correct boundary demarcation. Using the sculpting tools, an osseous guide for sinus window osteotomy was designed and connected to the implant surgical template (Fig 3). A removable membrane platform was then designed to interlock with the osseous guide (Figs 3b and 3c). The platform was meant to extend into the sinus to serve as support for the elevated sinus membrane and for protection during implant osteotomy preparation. To function, the width of the membrane platform was designed slightly narrower than the upper rim of the sinus window osseous guide (Figs 3b and 3c), while the length of the platform was determined by the virtual implant positions, which were later confirmed with cross-sectional views (Fig 4). The IOMG was then exported as separate STL files. The IOMG surgical template was reimported to the implant planning software, aligned to the first implant surgical template design, and the cutting paths were verified to ensure that the planned osteotomies were in the correct position and configuration (Figs 4a to 4d). Upon acceptance, the IOMG surgical template and the 3D bone segmentation were imported into 3D printing software (Netfabb, Autodesk) and fabricated by means of additive manufacturing technology (Straumann

![Fig 2](image1.png) **Fig 2** Digital data registration. (a) Segmented dentition (white) and maxilla (gray). (b) Alignment of postextraction digital scan to segmented dentition using three common landmarks. (c) Teeth segmentation disabled to improve visualization. (d) Preoperative digital scan aligned to postoperative digital scan to serve as a reference for correct implant positioning.

![Fig 3](image2.png) **Fig 3** (a) Surgical template design. (b) Membrane platform pathway. (c) Membrane platform attached to osseous guide.
P30+, Straumann). The printed models were postprocessed and tested before surgery. Finally, the 3D-printed surgical template was sterilized using an autoclave.

**Surgical Procedure**

Antibiotic prophylaxis (amoxicillin 2 g, GlaxoSmithKline) was administrated 1 hour prior to surgery. The patient was anesthetized using local infiltration with 2% lidocaine hydrochloride with 1:50,000 epinephrine (Lignospan Standard, Septodont). Two vertical releasing incisions were made, and a full-thickness mucoperiosteal flap was elevated to expose the alveolar crest and lateral wall of the maxillary sinus. The osseous part of the surgical template was seated, and its fit was confirmed through direct visualization through the inspection windows. The implant-osseous surgical template was used to outline the sinus lateral window. Piezosurgical tips were utilized for sinus window osteotomy preparation followed by gentle detachment of the sinus membrane from the sinus cavity floor. The sinus floor elevation procedure was successfully performed without membrane perforation (Figs 5a and 5b). The membrane platform was then inserted and attached to the osseous guide (Fig 5c). Implant osteotomies for the first and second premolar sites were prepared through the osseous guide according to presurgical implant planning and following manufacturer guidelines (Guided Surgical Kit, Straumann; Fig 5d). After removal of the membrane guide, deproteinized bovine bone mineral (Bio-Oss, Geistlich Pharma) was packed into the sinus, and two implants (Bone Level NC 3.3 × 10 mm, Straumann) were placed through the implant-osseous guide with 25 Ncm of insertion torque. Primary stability was achieved in both implant sites. The sinus window was then covered with a resorbable collagen membrane (Bio-Gide, Geistlich Pharma). Flaps were closed passively, and primary closure was achieved using polytetrafluoroethylene suture material (Gore-Tex, W.L. Gore & Associates). A small-volume CBCT was taken for postoperative evaluation (Fig 6).

**DISCUSSION**

The use of surgical templates for sinus floor elevation procedures has been previously described; however, its combination with an implant surgical template along with the design of a stabilizing/protective membrane platform has not been reported in the literature. The present clinical report provides a successful proof of concept for the utilization of a multifunctional template designed to guide the sinus floor elevation and simultaneous implant placement, while providing an attachable platform that serves as a membrane stabilizer and protecting shield. The customization made in the present clinical report allowed for a controlled sinus floor elevation and secure implant placement, mitigating some of the risks associated with the procedure.
Sinus floor elevation is a reliable option to augment the posterior maxilla. According to Pjetursson et al, the placement of dental implants in combination with maxillary sinus floor elevation is a reliable treatment approach, and it demonstrates high implant survival rates. Their systematic review revealed 3-year survival rates of 96.3% to 99.8% depending on the grafting material used, with the lowest annual failure rate (0.1%) observed in sites augmented with autogenous bone graft particles with simultaneous insertion of rough-surface implants, followed by the use of bone substitutes alone or combined with autogenous bone. Nonetheless, for one-stage sinus elevation procedures, the mean prevalence of membrane perforations was 19.5%. Although the rates of complications derived from sinus membrane perforation are minimal, when complications occur, they can lead to excessive bleeding, loss and contamination of grafting material, dislodgement of grafting material with potential blockage of maxillary sinus ostium, and chronic inflammation. The utilization of a piezoelectric instrument and careful detachment of the sinus membrane during instrumention is critical to reduce the risk of sinus membrane perforation. Moreover, methods to protect the membrane from being damaged during the elevation procedure should also be considered, especially if the treatment plan allows for a one-stage sinus floor elevation where the membrane must be protected from the osteotomy drills.

Mandelaris and Rosenfeld were the first to describe the use of 3D imaging and CAD/CAM technologies for the fabrication of a sinus floor elevation surgical template. In their report, eight patients were successfully treated with the use of prototype cutting guides for sinus floor elevation. Among the patients treated, four of them have undergone sinus floor elevation with simultaneous implant placement. Although successful, the clinical report did not provide information as to whether the sinus surgical template was modified to accommodate for a stabilizing platform, nor did it report the rate of complications during the procedure. Similar to the present clinical report, they used implant planning software to determine the extension of the sinus floor elevation based on their implant planning position. However, the lack of a digital intraoral scan may have negatively interfered with the correct seating of the surgical template, reducing its overall accuracy.

Zaniol et al used sinus floor elevation templates to test the low window sinus elevation technique proposed earlier by the group. In a retrospective case series, the authors treated 22 patients who had 28 interventions (sinus floor augmentation) using stereolithographic surgical templates. No occurrences of sinus membrane tearing or other surgical complications ensued. Additionally, patients healed uneventfully and reported a high degree of satisfaction with minimal facial swelling. The use of a CAD/CAM surgical template allowed for a standardized window preparation,
providing a significant advantage for the reproducibility of their proposed technique.

The incorporation of a sinus floor elevation surgical template to an implant surgical template is a promising approach, as it may increase the precision of the window access and provide better window positioning relative to the implant site, improving the overall outcome of the surgical procedure. However, due to the use of multiple data sets and software, the time needed for planning, designing, and manufacturing is substantially increased. It must be noted, though, that despite the increase in planning time, the use of the multifunctional surgical template may potentially shorten the time for the surgical procedure itself. Specific anatomical structures can impede the surgical template from seating correctly, particularly the curvature of the maxillary alveolar process. To overcome such a problem, when designing the surgical template, the authors included an offset of 3 mm from the bone. This allowed for an easier maneuvering of the surgical template. Nevertheless, it is recommended to print a prototype of the maxilla so the path of insertion of the surgical template is verified prior to surgery.

CONCLUSIONS

This clinical report demonstrates the value of CAD/CAM digital technologies to modify an implant surgical template for a one-stage sinus floor elevation procedure. However, the outcome must not be generalized, as it requires more investigations in further clinical trials.

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