Custom-Made Titanium Mesh for Maxillary Bone Augmentation With Immediate Implants and Delayed Loading

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Introduction

During the past 30 years, guided bone regeneration (GBR) has been successfully performed to treat fenestration, alveolar dehiscence, extraction sockets, and various alveolar ridge deficiencies. Providing spaces using barrier membranes combined with bone graft materials contributes to the best long-term stability of the newly augmented site. As a result of the ongoing research on GBR, many methods to increase bone volume have improved, various materials have been studied to induce new tissue growth, and numerous barrier membranes have been developed for different clinical situations.[1]

Titanium-reinforced polytetrafluoroethylene (PTFE) membranes stabilized with pins and screws are often considered the most predictable technique for increasing bone volume in larger alveolar ridge deficiencies prior to or during implant surgery.[1] Titanium mesh shows similar results for alveolar ridge deficiencies because of its excellent mechanical properties for the stabilization of bone grafts such as high strength, low density, plasticity, and low weight. In addition, its rigidity provides space maintenance and prevents contour collapse, its smooth surface decreases bacterial contamination, and its stability wards off graft displacement.[2] New advances in tissue engineering technology are significantly improving clinical performance with this type of barrier. The use of computer-aided design (CAD) and computer-aided manufacturing (CAM) in health care fields such as dentistry has allowed manufacturers to go beyond previous limits and obtain various morphologies from different devices with high accuracy, thereby increasing treatment opportunities in some clinical situations.[2,3] This technology combined with a selective laser melting machine can provide porous titanium structures with complex geometries that control the internal architecture. The main advantage of this technology is that it can produce custom-made devices for bone augmentation that are individually suited for patients requiring implant rehabilitation.[4]

We investigated the basic principles of digital workflow and the surgical steps of a novel type of custom-made titanium mesh (Ti-mesh), validated this surgical approach for bone augmentation in an edentulous atrophic maxilla, and analyzed the stability of the augmented bone after 1 year of follow-up.

Case Description

A 56-year-old male patient presented with a completely edentulous maxilla (Figure 1) and no general contraindications to oral surgery; he asked for fixed rehabilitation.

Preoperative orthopantography (Figure 2) showed a sufficient bone height to place standard implants, but computerized tomography (CT) highlighted insufficient bone width due to moderate horizontal bone resorption in the anterior maxilla. Because of the observed implant fenestration and dehiscence in the anterior maxilla (Figure 3), a horizontal bone augmentation procedure was planned, to be conducted simultaneously with implant placement.

A customized Ti-mesh was designed based on CT data using CAD-CAM software (BTK Opera Software, BTK, Biotec srl, Polovaro di Dueville, Italy). The digital workflow included the following steps: DICOM files of CT were used to create a 3-dimensional (3D) model of the maxilla (Figure 4), bone volume was horizontally increased and shaped to reconstruct the atrophic maxilla, a 0.3-mm layer was placed on the augmented maxilla to cover the whole bone volume (Figure 5), and finally, a virtual mesh was created from the layer, choosing structure, weave, fixation holes, and margins that fit perfectly over the borders of the bone defect (Figures 6 and 7). After software elaboration, the data were used to realize the customized Ti-mesh using a laser-sintering 3D printer (ProX-DMP100, 3D System, Rock Hill, SC).

After local anesthesia, a mid-crestal incision was made from one maxillary tuberosity to the other, and a full-thickness flap was raised to expose the maxillary jaw. After preparation of implant sites, four tapered double-lead thread

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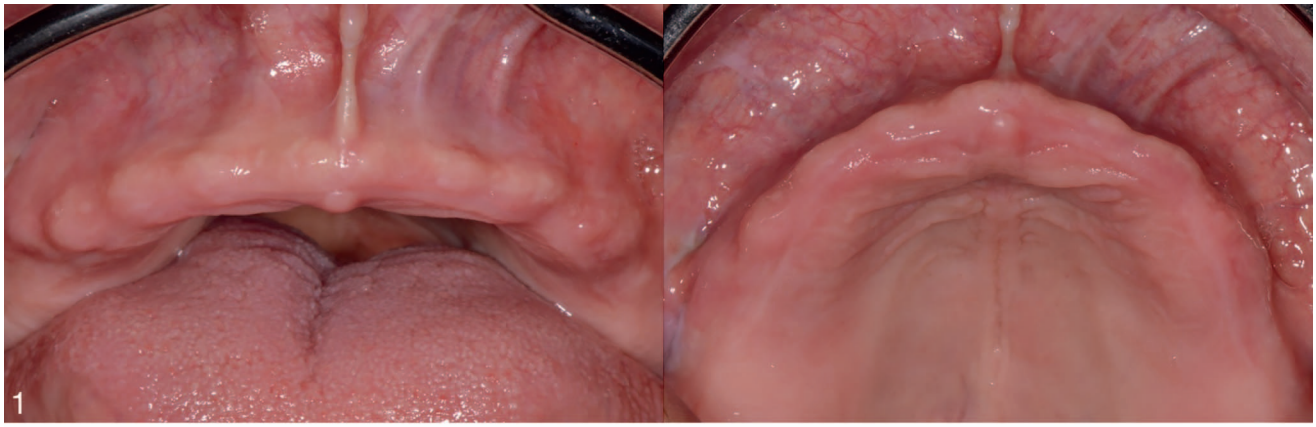
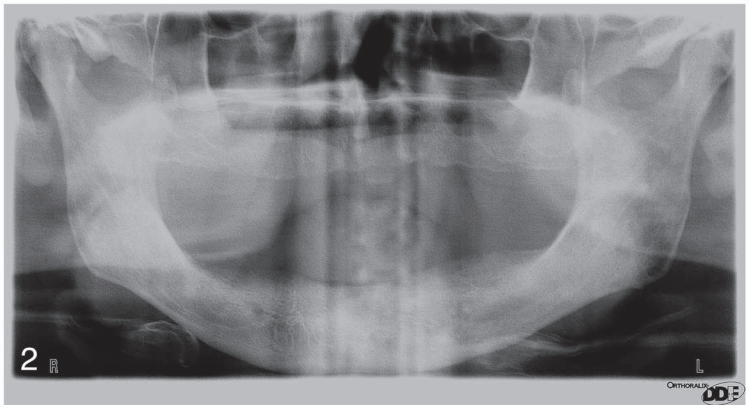
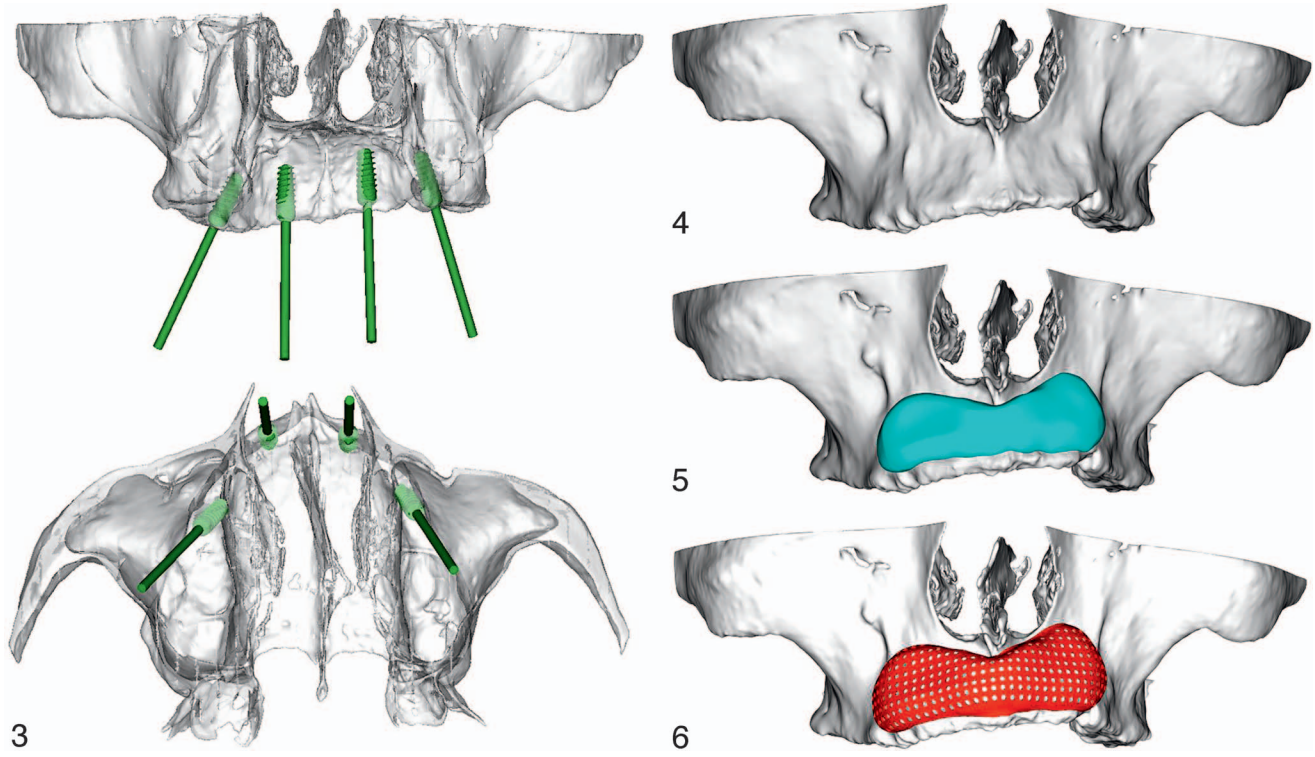




Figures 1 and 2. Figure 1. Frontal and occlusal view of atrophic maxilla. **Figure 2.** Preoperative ortopanthomography.



Figures 3–6. Figure 3. Digital implant placement planning. Because of severe horizontal bone atrophy, the previsualization showed implant fenestrations. **Figure 4.** Maxilla computer-aided design (CAD) rendering from computerized tomography data. **Figure 5.** CAD design of bone augmentation volume. **Figure 6.** CAD design of titanium mesh.

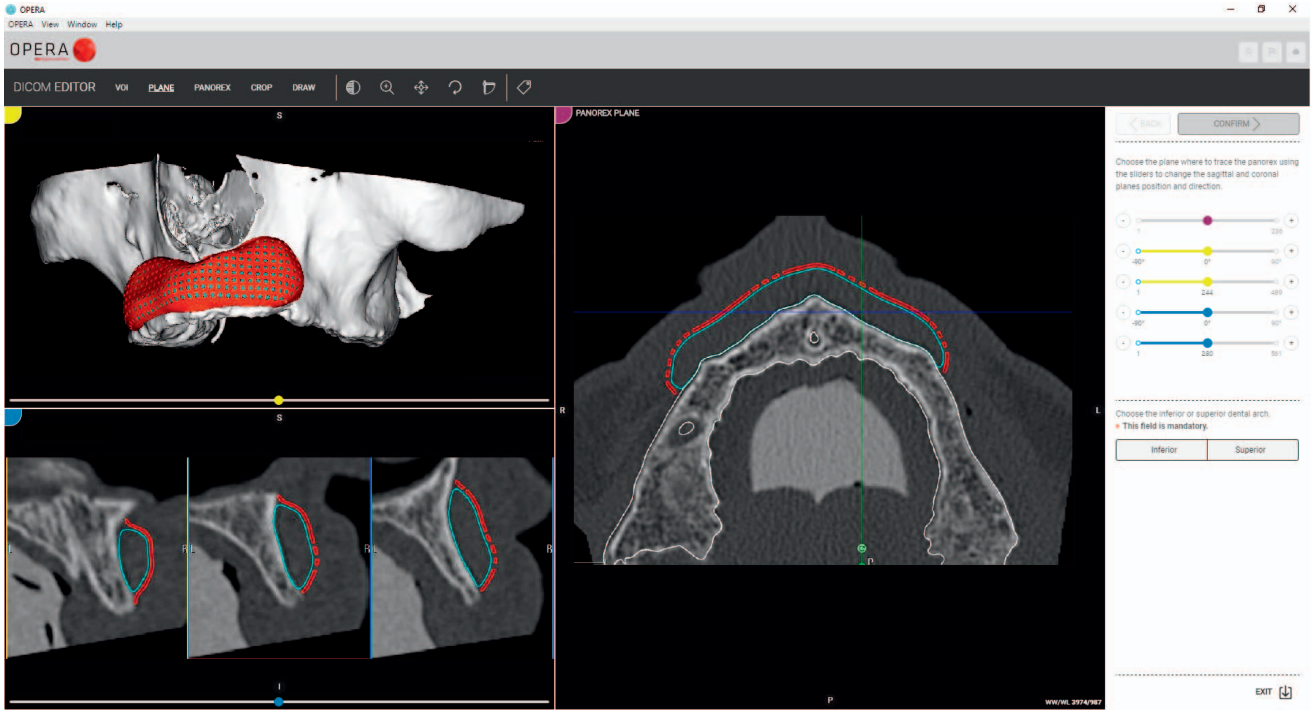


Figure 7. Digital titanium mesh (Ti-mesh) computer-aided design workflow. The space that will be occupied by biomaterial is represented in light blue, while in red is figured the Ti-mesh. The titanium grid is designed and printed to precisely adapt to bone anatomy.

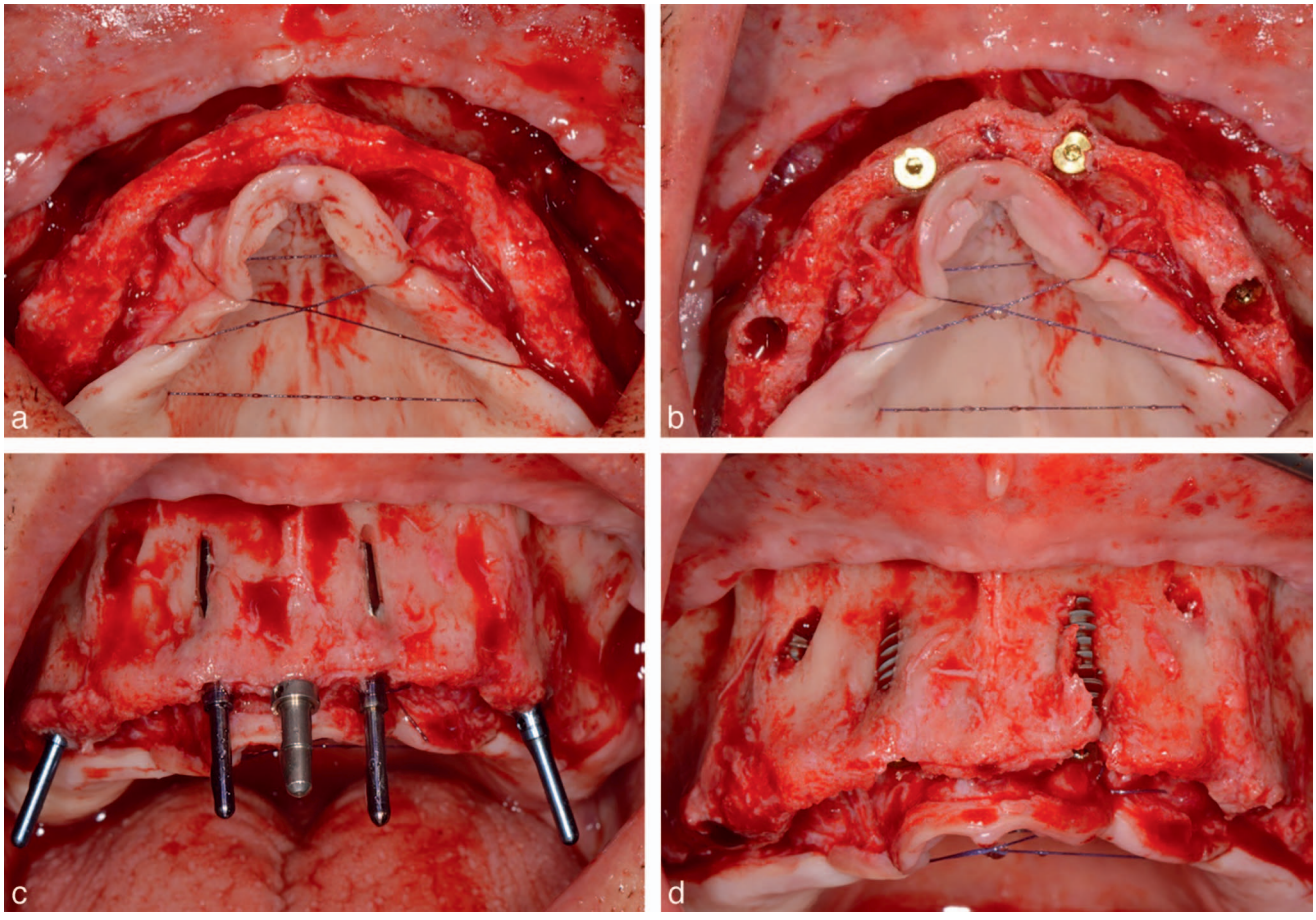


Figure 8. Surgical implant placement phases. The previsualization of fenestrations shown in Figure 4 revealed to be true in reality (d).

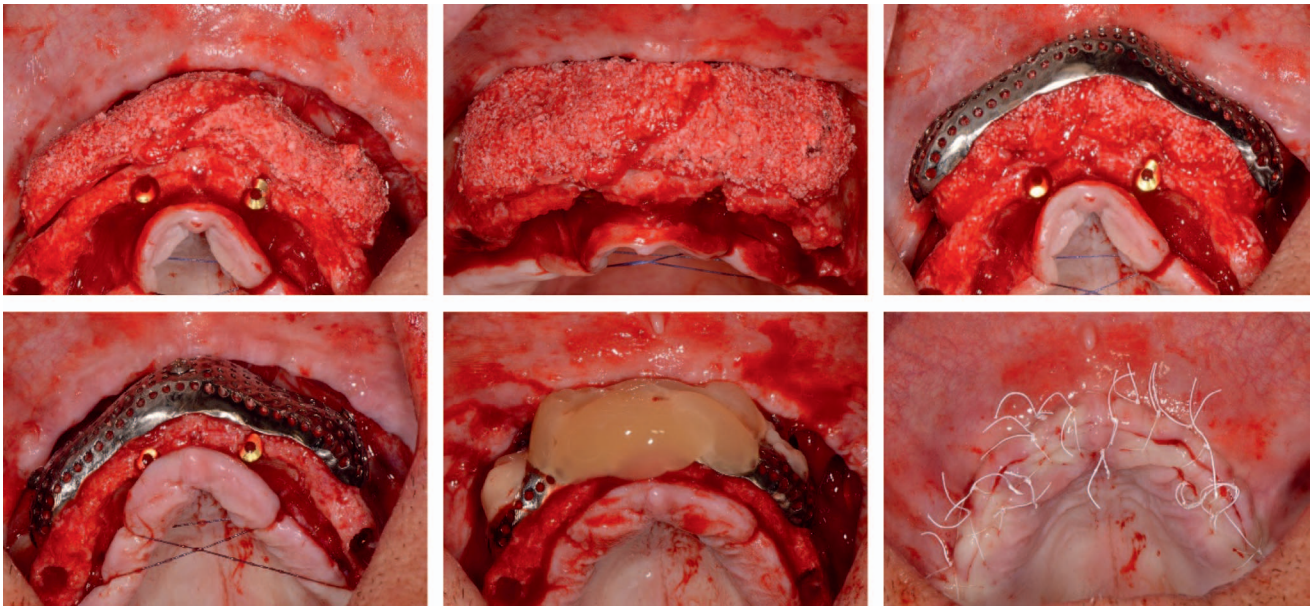


Figure 9. Biomaterial application under titanium mesh and plasma-rich growth factor.

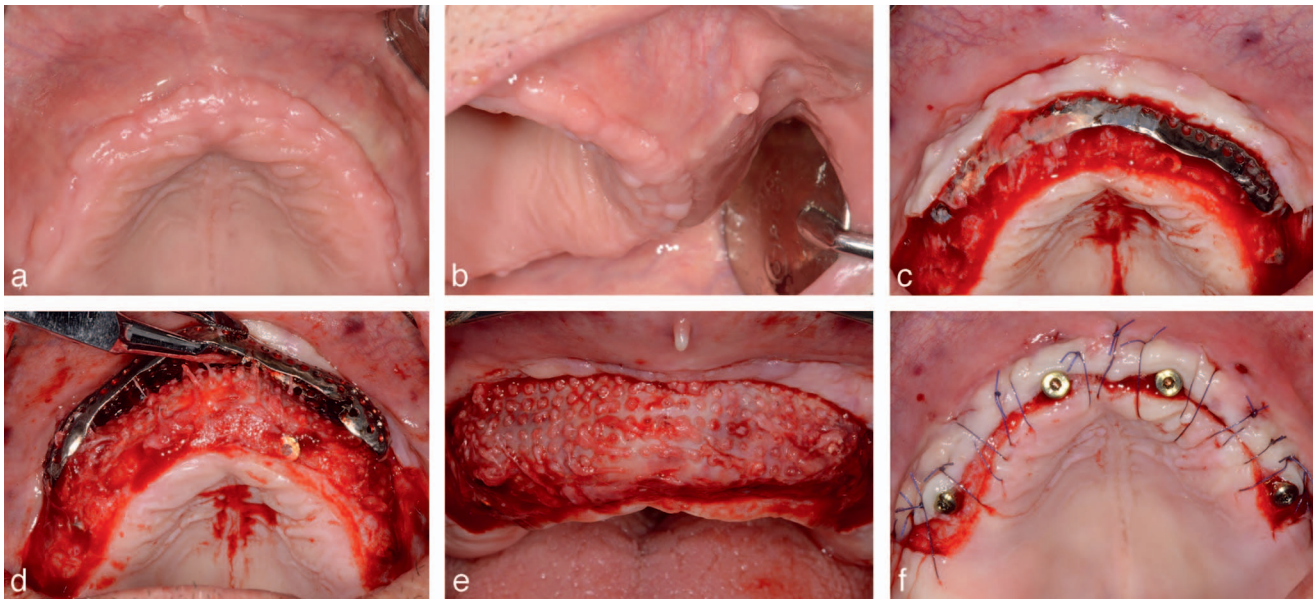


Figure 10. Second-stage surgery after 6 months. (a, b) Augmented maxilla in frontal and lateral view. (c, d) Grid exposure and removal, detaching from pseudo-periosteum. (e) Augmented bone volume. (f) Healing abutments and soft-tissue augmentation.

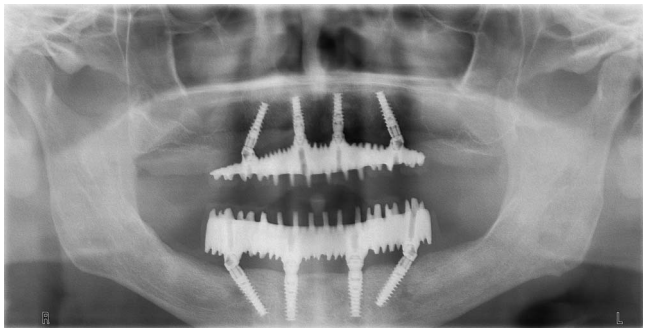
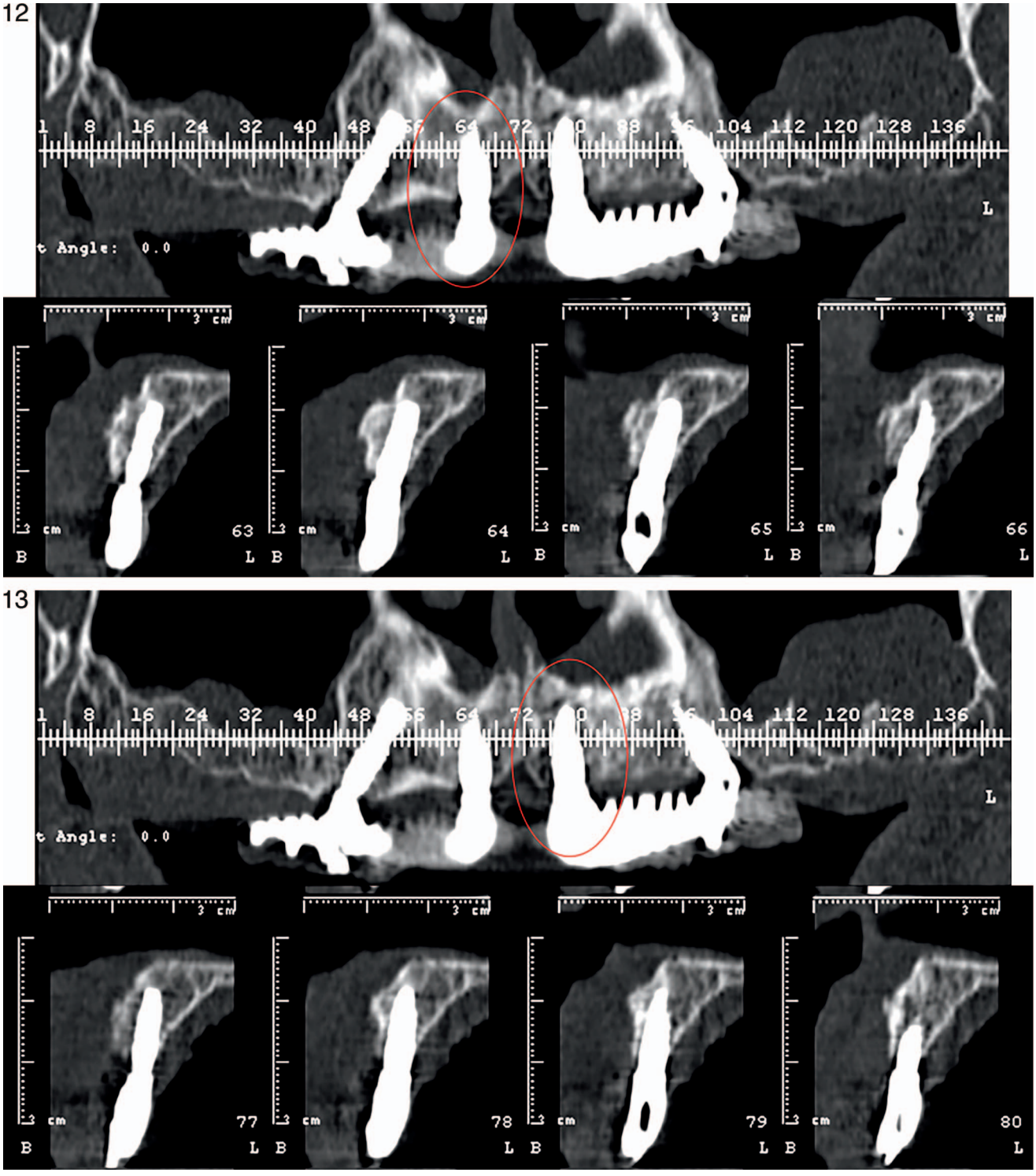


Figure 11. Orthopantomography after prosthetic loading.

implants (NobelActive, Nobel Biocare, Zurich, Switzerland) were placed in the maxilla (Figure 8) and in the mandibular bone. A 50:50 mixture of autologous bone and xenograft (Zcore Porcine Xenograft, Osteogenics, Lubbock, Tex) was enhanced with plasma rich in growth factors (PRGF; PRGF-Endoret; BTI Biotechnology Institute, Vitoria, Spain) and used as grafting material to fill the Ti-mesh that was fixed to the anterior maxilla using titanium mini-screws (Pro-fix System, Osteogenics). Then, PRGF membranes were applied over the Ti-mesh to facilitate the healing of soft tissue. After buccal flap passivation was obtained with periosteal incisions, a tension-free primary closure with 5-0 PTFE sutures was



Figures 12 and 13. Detailed computerized tomography images of implant bone, horizontal and vertical levels 1 year after loading.

completed (Cytoplast, Osteogenics; Figure 9). After 6 months of submerged healing, reopening surgery for Ti-mesh removal and implant exposure was performed (Figure 10). After 3 months, the definitive full-arch fixed prosthesis was delivered to rehabilitate the esthetics and function of the patient (Figure 11).

Discussion

As shown in this case report, the digital workflow is a safe and predictable procedure because of the quality of CT image acquisition and the printing precision of Ti-mesh.[3,4] A customized Ti-mesh can have many advantages. This fabrica-

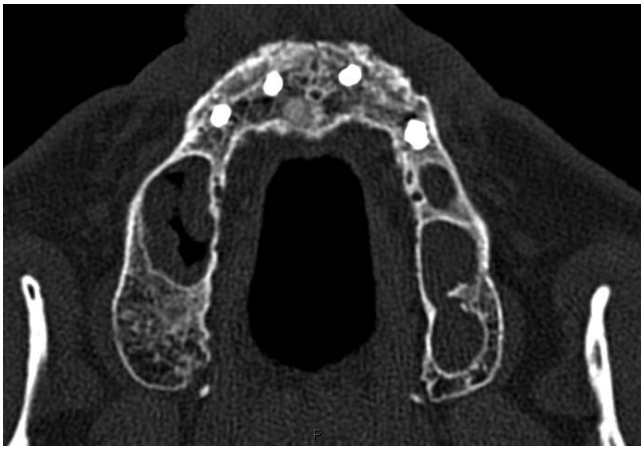


Figure 14. Computerized tomography 1 year after loading, occlusal view. Notice the native cortical level in the inner augmented bone and the newly formed cortical bone.

tion process offers a bended grid with neat and clean margins, without irregularities and imprecision that may harm soft tissue. The precise adaptation of the mesh to regenerative material and native bone may help reduce micro-movements. In addition, the fabrication process eliminates the need to manually adapt the mesh to the patient, which significantly reduces the working time, open flap period, risk of contamination, and, consequently, postoperative infections.[2–4]

The risk of early or late exposure is the main drawback of Ti-mesh and seems to correlate with wearing a mobile prosthesis and/or inadequate modeling of the mesh.[4,5] Accurate digital planning and a careful prosthetic protocol during the first 3 months of healing seem to be key factors for avoiding biological complications (ie, exposure of Ti-mesh). After removal of the Ti-mesh, a layer of connective tissue covering the newly formed bone, the so-called "pseudo-periosteum," was observed. This is indicative of a lack of bone regeneration due to infiltration of connective tissue across the mesh holes and does not allow for verification of bone density and features of augmented bone but seems to protect the bone in case of exposure.

After 1 year of loading (Figures 12 and 13), CT was useful for evaluating the structure and stability of the augmented bone. All implants were entirely surrounded by bone tissue on the buccal side, and there was a new cortical layer due to reorganization and remineralization of newly formed bone; the old cortical layer was still detectable in the scans (Figure 14). The rationale to place implants simultaneously with horizontal bone augmentation was based on a reference point to verify the reduction of augmented bone over time.

In summary, the advantages of 3D designing and printing a customized Ti-mesh are the high stability of the regenerative material, neat margins and no sharp edges, only 2 or 3 vestibular pins needed to fix the mesh, working time reduction, infection risk reduction, and previsualization of the result.

With proper patient selection, careful diagnostic procedures, and advanced surgical skills, this technique could become a valid alternative to standard Ti-mesh in the edentulous atrophic maxilla. The predictability of this technique permits simultaneous implant placement without compromising bone regeneration over the implants in cases of fenestration or dehiscence.

Conclusions

Within the limit of a case report, immediate maxillary implant insertion with simultaneous horizontal bone augmentation with customized CAD/CAM Ti-mesh is a promising technique. Comparative studies with longer follow-up and a larger population are required to validate this simplified approach.

Abbreviations

CAD: computer-aided design
CAM: computer-aided manufacturing
CT: computerized tomography
GBR: guided bone regeneration
PRGF: plasma-rich growth factor
PTFE: polytetrafluoroethylene
Ti-mesh: titanium mesh

Note

The authors declare no conflicts of interest.

References

1. Rakhmatia YD, Ayukawa Y, Furuhashi A, Koyano K. Current barrier membranes: titanium mesh and other membranes for guided bone regeneration in dental applications. *J Prosthodont Res*. 2013;57:3–14.

2. Otawa N, Sumida T, Kitagaki H, et al. Custom-made titanium devices as membranes for bone augmentation in implant treatment: modeling accuracy of titanium products constructed with selective laser melting. *J Craniomaxillofac Surg*. 2015;43:1289–1295.

3. Ciocca L, Ragazzini S, Fantini M, Corinaldesi G, Scotti R. Work flow for the prosthetic rehabilitation of atrophic patients with a minimal-intervention CAD/CAM approach. *J Prosthet Dent*. 2015;114:22–26.

4. Ciocca L, Lizio G, Baldissara P, Sambuco A, Scotti R, Corinaldesi G. Prosthetically CAD-CAM guided bone augmentation of atrophic jaws using customized titanium mesh: preliminary results of an open prospective study. *J Oral Implantol*. 2018;44:131–137.

5. Sagheb K, Schiegnitz E, Moergel M, Walter C, Al-Nawas B, Wagner W. Clinical outcome of alveolar ridge augmentation with individualized CAD-CAM-produced titanium mesh. *Int J Implant Dent*. 2017;3:36.