Modern CAD/CAM technology supports implantology

An individualized 3D-printed solution for complex bone augmentation

DR ALEXANDER VOLKMANN, JENA AND EISENACH, GERMANY

CAD/CAM-designed and -manufactured titanium meshes can be used in lieu of conventional titanium scaffolds for complex bone augmentation. This approach can offer various advantages, such as simpler clinical handling and reduced surgical time.

Dental implants allow an effective replacement of lost teeth, with high long-term survival rates [1–3]. Nevertheless, the long-term success and stability of implants directly correlate with the ridge contour, the bone quality, and with the width and height of the residual bone at the implant site [4,5]. In spite of the development of various augmentation techniques and materials, the reestablishment of an adequate amount of bone in areas with major ridge deficiencies, especially vertical and combined defects, remains challenging.

Extensive in vivo pre-clinical and clinical studies evaluated healing processes via histological and radiological outcomes of various augmentation procedures, depending on location and size of the defect [6]. Techniques such as interpositional grafting or distraction osteogenesis, use of form-stable reinforcements provided by form-stable membranes, titanium meshes, bone shields, bone blocks, or the osseous walls themselves have been extensively used.

Conventional titanium meshes

Conventional titanium meshes were first used for the reconstruction in cases of osseous maxillo-facial defects, and secondarily introduced for the osseous restoration of deficient edentulous maxillary ridges [7–9]. Moreover, they were used for augmentation in localized alveolar ridge defects with simultaneous and with subsequent implant insertion [10–12]. Further clinical studies demonstrated consistent results for both horizontal and vertical bone reconstruction with this titanium mesh technique [13], and a recent systematic review showed that titanium meshes are recommendable over other techniques when there is a need for more than 3.7 mm of vertical augmentation in alveolar ridges [14]. In addition, use of a form-stable grid to create space offers advantages, such as the possibility of enhancing the osteogenic potential of the graft by mixing autologous bone chips with particulate bone substitute material and thus avoiding the need for bone block harvesting and time-consuming adap-

1 I The radiographic image before implant removal shows extensive bone defects.

2 I The clinical situation before explantation shows a severely diminished ridge dimension.
Tomography (CT) or cone beam computed tomography (CBCT) scan data of the bony defect and a digital workflow system, individualized titanium mesh cages can be created for a precision fit that accurately reflects the specific data provided. Yxoss CBR (ReOss Ltd., Filderstadt, Germany) is a 3D-printed titanium scaffold engineered and developed as a customized treatment for patients with complex alveolar ridge defects. It combines the advantages of 3D imaging, planning tools and 3D printing.

The following two case reports describe the treatment protocol from diagnosis to conclusion, with step-by-step description of the treatment procedure adopted in each case.

**Case 1**

The case is presented in order to demonstrate a practicable solution for moving from severe peri-implantitis to the complete restoration of the intraforaminal area, using a new implant-supported, fixed prosthesis in an edentulous mandible, performed in an outpatient setting.

A 79-year-old female patient wearing a ten-year-old fixed implant restoration (first implant treatment in 2006) presented with increasing bone loss caused by progressive peri-implantitis. Because of the impossibility of having a conventional prosthesis attached in her edentulous mandible, she requested a new fixed implant prosthesis. Indeed, the implants had been loaded after conventional bone healing (three months) with a bar-end cover-denture prosthesis (Fig. 1). After four years in function, a peri-implantitis treatment was performed. Due to progressive bone loss and inflammation combined with permanent pain, all implants had to be explanted six years later, in 2016.

The basic situation was marked by a major 3D bone defect in area 35 to 45. The inflammation and the subsequent explantation had left an undentulous and scar-penetrated soft tissue. In the intraforaminal area, there was no attached gingiva. The floor of mouth communicated with the oral vestibule.

Using dental cone-beam computed tomography (CBCT), an augmentation with Yxoss CBR was planned (Figs. 2 to 4). The titanium scaffold was filled entirely with Geistlich Bio-Oss (Geistlich Pharma AG, Wolhusen, Switzerland) due to the complete absence of autologous bone. The scaffold was fixed using three screws (MidFace 1.7; Stryker, Portage, MI, USA) and covered with a Geistlich BioGide membrane (Figs. 5 and 6). The flap was adapted to ensure complete soft-tissue closure.

Antibiotic therapy with Amoxicillin 2 grams per day was started, and during the following days, primary wound healing was uneventful. After ten days, the stitches were removed, and the patient received no provisional prostheses.
To harmonize the soft tissue, an apical vestibuloplasty was performed (Fig. 14). After seven days, the stitches were removed (Fig. 15), and the clinical situation was checked after placement of ceramic abutments (Figs. 16 and 17). The patient was then sent to her home dentist for final restoration, where an initial telescopic zirconia overdenture followed by secondary galvanic passive fit was provided (Fig. 18).

After five weeks, dehiscence occurred in area 32 to 34 (Fig. 7). Since there were no signs of infection, the area was cleaned with chlorhexidine gel 1%, and the patient was asked to be very careful during eating.

After five months, the dehiscence healed, and the Yxoss CBR was removed (Figs. 8 to 10). Even though there had been soft-tissue dehiscence, the bone regeneration was satisfactory. To allow for formation of fully functional bone and soft tissue at the time of implantation, implant placement was performed two months after mesh removal (Figs. 11 and 12).

The horizontal dimension of the ridge was approximately 8 mm; for that reason, a drilling template was not necessary. To get a gentle initial loading on the implants, healing abutments were placed for soft tissue modeling. After three months, implant healing was checked by radiography (Fig. 13). To harmonize the soft tissue, an apical vestibuloplasty was performed (Fig. 14).

After seven days, the stitches were removed (Fig. 15), and the clinical situation was checked after placement of ceramic abutments (Figs. 16 and 17). The patient was then sent to her home dentist for final restoration, where an initial telescopic zirconia overdenture followed by secondary galvanic passive fit was provided (Fig. 18).
11 I Implantation of four Camlog Screw Line implants three months after scaffold removal.

15 I Removal of the stitches.

13 I Radiographic image after implant placement.

14 I An apical vestibuloplasty is performed to harmonize the soft tissue.

12 I Placement of the healing abutments for soft-tissue modeling.

16 I Clinical situation after placement of four ceramic abutments.

17 I Postoperative panoramic radiograph after abutment placement.

18 I Final prosthetic restoration ten months after 3D regenerative procedure.
Case 2
The second case is likewise intended to demonstrate a possible solution for moving from a severe juvenile periodontitis and malocclusion situation (mandibular protrusion) to a complete restoration using the Yxoss CBR scaffold, in an outpatient setting.

A 30-year-old female patient wearing a provisional prosthesis since orthodontic treatment and extraction of teeth 11 and 21 in 2010 presented with increasing bone loss caused by progressive periodontitis. She requested restoration of the anterior region of the maxilla.

The basic situation was marked by a major combined vertical and horizontal bone defect in area 11 and 21 (Fig. 19). Using CBCT, an augmentation with an Yxoss CBR was planned (Figs. 20 and 21). After preparation of the soft tissue with a dual-sided split-flap technique, and of the hard tissue via bone drilling (Figs. 22 and 23), the titanium scaffold was produced specifically for the patient. It was fixed with two screws (Midface 1.7, Stryker) and filled with Geistlich Bio-Oss (Fig. 24). A Geistlich Bio-Gide collagen membrane shielded the graft from the soft tissue (Fig. 25).

After four months, the soft-tissue conditions were clinically stable and free of any dehiscences (Fig. 26). A ridge incision was selected for removal of the grid structure. After removing the fixing screws, the grid structure could be carefully split into two parts by applying small extrusion movements to the target breakpoint with the periostal elevator, and was easily removed (Fig. 27).

Implant placement was performed delayed by two months in order to obtain fully functional bone and soft tissue of good quality (Fig. 28). The horizontal ridge was approximately 7 mm. A drilling guide was used (Fig. 29), as well a surgical indexing process for recording the position of the implants relative to adjacent teeth and the opposing occlusion (Fig. 30). The wound healing process proceeded uneventfully, and the stitches were removed after seven days (Fig. 31).
I Reopening after two months shows vital regenerated bone with a 7 mm horizontal bone gain.

Indexing of the implant position.

Clinical situation four months after augmentation.

The 3D scaffold is removed using the pre-defined breaking points.

Reopening after two months shows vital regenerated bone with a 7 mm horizontal bone gain.

Implant placement in prosthetically correct position using a drilling guide.

Indexing of the implant position.

Clinical situation with the closed wound seven days after implant positioning.
After three months, the provisional crowns were placed (Fig. 32), the stitches were removed after seven days (Figs. 33 and 34), and the soft tissue was left to regenerate (Fig. 35). The radiological evaluation was performed two months after provisional crown placement (Fig. 36), and the final restoration planned for approximately three months after provisional loading using a titanium adhesive base with veneered zirconia and Empress ceramic veneered crowns.

Conclusions
The vertical and horizontal regeneration of resorbed alveolar ridges remains a challenging surgical procedure, especially in cases of extensive bone atrophy. A wide variety of augmentation techniques have been proposed to restore adequate bone volume. Individualized CAD/CAM-produced titanium mesh, such as Yxoss CBR, has been successfully used more than 30 times in our private practice for bone reestablishment, in patients with disparate initial conditions and requirements. Even though the titanium scaffold still presents the risk of soft tissue dehiscence with exposure of the graft and possible partial loss of graft material due to the stiffness of the titanium mesh with mechanical irritation to the mucosal flap [15,20,21], it combines the advantages of 3D-imaging, planning tools and 3D-printing. Time-consuming impressions, cutting, shaping and adapting are no longer necessary, and thus the surgery time is reduced. Sharp edges from cutting conventional meshes are eliminated. Furthermore, being customized, the mesh has an optimized fit to the individual anatomy of each patient and preserves volume for osteogenesis. In contrast to other techniques, the Yxoss CBR technology allows combined autologous and xenogeneic bone graft augmentation. Due to their low resorption rates, xenogeneic biomaterials such as Geistlich Bio-Oss protect the grafted bone volume, and given their osteoconductivity, the materials support rapid and integrated bone growth [22–24].

Autologous bone combines osteogenesis, osteoconductivity and osteoinductivity [24]. Moreover, the Geistlich Bio-Gide collagen membrane, as a preserved native bilayer structure, effectively protects the graft from soft tissue ingrowth [25] and mechanical dislocation [26]. The combination of autologous and xenogeneic products placed together with a titanium scaffold enables us to rebuild even major 3D defects in our daily outpatient practice.

The references are available at www.teamwork-media.de/literatur

Contact address
Dr. Alexander Volkmann
Leutragraben 2
07743 Jena
Germany
volkmann@facelookconcept.de