CAD/CAM technology supporting successful implant therapy
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Modern implantology opens up new treatment options for individuals with only minimal or no remaining dentition. Innovative implant designs such as the Trabecular Metal Dental Implant (Zimmer Dental, US-Carlsbad) with a midsection made of highly porous (80%) tantalum biomaterial with a trabecular structure allow for immediate or early loading. The use of advanced CAD/CAM technology in implant prosthodontics makes sure that precisely fitting removable or fixed dentures are obtained. As a whole, these treatments usually lead to high patient satisfaction and long-term treatment success.

Trabecular Metal material has been in clinical use in orthopedics for more than ten years already. The dental implant utilizing this material was introduced by Zimmer Dental in early 2012. According to the manufacturer, the bio-compatible Trabecular Metal material made of tantalum has a three-dimensional structure that is comparable to cancellous bone and offers up to 80 percent porosity for bone on-growth and in-growth. Initial study results indicate that with this new implant, immediate or early loading protocols are safe and effective.

However, implant success is not only determined by the implant alone, but for a large part depends on accurate design, precise fit and proper occlusion of the restoration. With an increasing number of teeth missing and a growing complexity of the implant-based restoration, the accuracy of fit becomes ever more important, since implants, unlike natural teeth, are rigid and have no periodontal ligament to compensate for slight inaccuracies. In my experience, the required precision is best obtained if advanced CAD/CAM technologies are used for the production of the restoration. In this way, even complex screw-retained structures like bars or long-span bridges can be produced – provided that only high-end components are used.

The following case example describes the workflow of choice involving Trabecular Metal Implants and a removable denture with a bar designed using the Zfx CAD/CAM system (Zfx, D-Dachau).

Patient case
A 75-year-old male was referred to our practice by his general dentist with a chief complaint that the maxillary anterior teeth were failing. The patient wished to have them replaced with an implant-supported restoration. A review of the patient’s medical history showed that he had hypertension, heart condition and arthritis that caused severe back problems. His dental history revealed a well-restored lower dentition. In the maxilla, there were six remaining natural teeth (from the right first premolar to the left lateral incisor) and two Tapered Screw Vent Implants (Zimmer Dental) in the posterior region on the right restored with two splinted crowns (Figs. 1 to 3).

Fig. 1: Initial situation
On the radiograph and during clinical examination, severe bone loss was detected in the edentulous posterior region of the maxilla. Since the restorations on the remaining maxillary anterior dentition were failing and the prognosis of those teeth was poor, there was a need for immediate action. A very strong gag reflex of the patient prevented him from using any type of conventional removable denture.

**Treatment plan**

Therefore, two different treatment options were discussed with the patient: the first one suggested the extraction of the remaining maxillary teeth and their immediate replacement with four Trabecular Metal Implants. The second option involved a left maxillary sinus lift to allow the placement of posterior implants. The patient decided to go with the tooth extraction and immediate implant placement.

Regarding prosthetics, the patient was asked to choose between a bar-supported removable overdenture and a fixed, screw-retained complete denture. He decided in favor of the removable overdenture that would allow for better hygiene access and a tight seal of the denture flanges resulting in improved speaking ability. In this case, it was planned to use the two existing implants to support the bar.

**Surgery**

After obtaining the patient’s consent, under intravenous conscious sedation using Midazolam (10 mg) and Fentanyl (150 mcg) along with local anesthesia, the remaining maxillary teeth were extracted with the patient being in semi-supine due to his back problems (Fig. 4). The extraction sockets were thoroughly debrided. Then, the osteotomies were performed palatally in D3 bone (Fig. 5). Trabecular Metal Implants of the type TMT with microtexturing to the top were placed in the extraction sockets of the right first premolar (diameter: 4.1 mm, length: 13 mm) and the left lateral incisor (diameter: 4.1 mm, length: 11.5 mm) as well as in the healed site of the left first premolar (diameter: 4.1 mm, length: 13 mm).
An implant of the type TMM with 0.5 mm machined titanium in the coronal section (diameter: 4.7 mm, length: 13 mm) was inserted into the extraction socket of the right central incisor (Figs. 6 and 7). For all implants, a high primary stability with a torque of over 35 N/cm was achieved.

Immediately afterwards, the restorations on the Tapered Screw Vent Implants were removed, six impression posts placed and a polyvinylsiloxane fixture level impression was taken due to the strong gag reflex. Then, four healing abutments were placed on the new implants and locators on the existing ones. A mini implant was placed to support a provisional palateless overdenture. The critical gaps between the implants and the extraction sockets were grafted using Puros Cortico-Cancellous bone particulate mix (Zimmer Dental) and a cross-over mattress suture was performed using 4-0 Vicryl suture (Figs. 8 and 9). The provisional was delivered and the patient was given the post-operative instructions. During the follow-up visits, healing was uneventful.
**Virtual design of the bar**

On the basis of the polyvinylsiloxane impression, a master model was produced in the dental laboratory. A verification jig was used to check its accuracy. In addition, a wax up and a removable gingival mask were fabricated in order to establish the desired shape of the planned restoration. The models of maxilla and mandible as well as the wax up and artificial gingiva were sent to Zfx Munich (D-Dachau) for computer-aided design and manufacturing of the screw-retained bar.

In this milling center, the model of the maxilla was digitized with the wax up as well as with and without artificial gingiva. Then, scan adapters developed by Zfx were screwed onto the model with a predefined torque of 15 Ncm for exact localization of the implants and their axes and the model was scanned again. The scanner used in the milling center is Zfx Evolution (Zfx, D-Dachau), a structured light scanner developed in the company's center of innovation in Bolzano (Fig. 10).

According to the manufacturer, a high precision with deviations of less than 10 µm is obtained in the complete scan volume. Thus, the captured data is suited as a basis for the virtual design and computer-aided production of complex, screw-retained structures such as the bar that was ordered in the present case. The specific scan adapters allow for a precise transfer of the implant positions into the virtual world.

The data sets were imported into the Zfx-CAD-Software (Figs. 11 to 13), where the relevant patient data was entered. The implant positions were determined automatically with the aid of the scan adapters. Bar codes on these adapters ensure that the implant types, lengths and diameters are identified automatically and imported into the software from the implant library.
Then, the emergence profiles were marked on the gingiva. The virtual wax-up was shown on the master cast since full-contour shape of the planned restoration is needed for the software to generate an optimal bar design (Figs. 14 and 15).

The design proposal can subsequently be modified individually: it is possible to alter the design of the profile and to modify the parameters, e.g. the thickness, of the bar. The distance to the gingiva and the abutment design can be customized as well (Fig. 16). In the present case, the bar was modeled on the level of the gingiva. In addition, threads were designed to place locators on the bar, which should serve as retention elements (Figs. 17 and 18). Figure 19 shows the bar after completion of the design step.

The screw-retained bar was milled using the machine Zfx Ultramill and sent to the dental practice (Fig. 20), where it was tried in six weeks from the date of implant surgery.
Since it fitted very well, the bar was sent to the dental technician to build in the four locators (Fig. 21). Before processing of the overdenture, a final try-in of the bar was done (Fig. 22). Figures 23 and 24 show that the bar has a perfect fit into the overdenture.

The final delivery of the complete restoration took place eight weeks after implant placement. The bar with passive fit was torqued at 30 N/cm (Fig. 25). A radiograph was taken to verify the precise fit (Fig. 26). The occlusion and fit of the overdenture was verified (Fig. 27) and the patient was seen for a follow-up visit to adjust any sore spots.

Fig. 21: Checking the fit on the model.

Fig. 25: Placement of the bar.

Fig. 26: Radiograph of the final situation.

Fig. 22: Final try-in of the bar.

Fig. 23: The overdenture.

Fig. 24: A perfect fit of the bar into the overdenture is obtained.

Fig. 27: Overdenture in place.
Recently, a four-month post-operative check was performed and the patient was very pleased with the final outcome: according to him, the bar is very easy to clean and there is a great fit of the overdenture with no speech impairment (Figs. 28 to 30). The patient is placed on six-month recall to follow-up on the successful treatment.

**Conclusion**

With the described combination of innovative materials and techniques, it is possible to offer patients an implant treatment that leads to accurate results and high patient satisfaction. An immediate placement and early loading of the new implants enables us to reduce the time required for the therapy. The precise fit of the CAD/CAM bar makes sure that no adjustments are necessary and stresses on the implants are reduced to a minimum. Thus, an important precondition for long-term success of the implant and the restoration is fulfilled.

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