The treatment of toothless jaws—A case for CAD/CAM

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Prosthetic devices can be fitted in various ways. Digital technologies have left their mark in implantology and provide options for high quality solutions. Classical indications for implant-prosthetic treatments include dentures for the toothless jaw. For this type of denture, clinical studies document a high survival rate of about 85 to 90% with observation periods of up to 20 years.1,2 Various prosthetic concepts have established themselves for the fitting of superstructures according to the number of inserted implants.3 Generally, there is either a fixed denture mounted on six to eight implants and borne by these only, or a removable denture with a reduced number of implants.4

The selection of a suitable denture depends on subjective criteria—patient expectations, financial constraints—and on clinical aspects—anatomic criteria, technical and clinical reliability of implants and superstructure. Accordingly, the success of the prostheses depends on the following factors (Fig. 1):

- Subjective criteria (patient satisfaction and quality of life);
- Objective criteria (probability of survival); and
- Necessary maintenance effort during the lifetime of the denture.

Criteria for the selection of the type of denture

Fixed, as well as removable implant-prosthetic dentures in the toothless jaw, as opposed to the conventional full denture, have proven to significantly increase patients’ satisfaction and improve their ability to chew.6,7 Hence, the insertion of two to four implants can lead to a clear improvement of quality of life. Therefore, the removable implant-supported and implant-retained cover denture prosthesis is nowadays considered an effective therapy.

However, there was also evidence that, in particular, the choice of fitting elements in a removable denture, for example magnets, ball-heads, bridges and telescopes, has an influence on patient satisfaction. With respect to stability and retention power, as well as achievable patient satisfaction, a comparative cross-over study demonstrated that magnets are inferior to the fitting with ball-heads.6,7 A comparison of ball-head elements and overdenture attachments used for the fitting of an implant-retained cover denture prosthesis did not demonstrate any differences with regard to patient satisfaction.8 However, there proved to be a significant difference in the rate of technical complications.

Within an observation period of three years, prostheses fitted with ball-heads required 6.7 repairs, whereas the group of bridge-fitted prostheses required 0.8 repairs per patient only. Hence, overdenture attachments as fitting elements for removable superstructures guarantee high patient satisfaction. Owing to their low rate of technical complications, they require less maintenance than alternative fitting elements,9 which is an important criterion for the long-term success of the prosthesis.

High maintenance requirements demand more practice visits and take the time of both the patient and the care provider. Furthermore, if there are technical complications that have led to the failure of superstructure elements, an intervention by a dental technician might be necessary to reconstruct or replace individual components. This is also connected with additional costs in order to maintain function.

When evaluating overdenture attachment constructions as fitting means, the various types and forms available must be considered. On the one hand,
there are individually shaped bar attachments, and on the other hand, there is the classic round bar, which can be manufactured either by casting or by combination of pre-fabricated elements.

The overdenture attachment fitted on four implants is a classic fitting element for a purely implant-supported cover denture prosthesis in a toothless upper or lower jaw. A retrospective study with 51 patients compared individually shaped bar attachments and round bars for the fitting of cover denture prostheses. Twenty-six patients were equipped with round bars, while 25 patients received a superstructure with an individual bar attachment on four implants each. After a surveillance period of five years, the survival rate of the implants was 100%. Larger technical complications that required a renewal of the mounting elements occurred in the round bars only in the form of fractures in the extension areas. The fractures on the extensions of the overdenture attachments, which were exposed to high mechanical stress, were due either to porosities in the cast object or to inhomogeneities in the area of the points of attachment. Furthermore, it was determined that low-grade complications (activation of hanks) occurred three times as often in the round bars as in the bar attachments. Thus, two causes of defects can be deduced: firstly, defects due to faults in the manufacturing technique (casting and joining processes); and secondly, defects causatively connected with the design of the superstructure.

Two versions are described in the literature for the fitting of attachments in the toothless upper jaw: the fitting of attachments on four implants in the anterior segment and the fitting of two attachments on three to four implants on the lateral segments (mostly after a previous sinus floor augmentation). Additionally, for the application of attachments in the toothless upper jaw, data from clinical studies has been published. Both attachment concepts featured almost identical survival rates after five years: 98.4 % for the attachments in the anterior segment and 97.4 % for the attachments fitted on six to eight implants in the lateral segments of the upper jaw.

In particular, fitting by bar attachments appears to be a therapeutic means with guaranteed success of the fitting of purely implant-supported cover denture prostheses in the upper and lower jaw. It excels with a low rate of technical complications, as well as low maintenance requirements. Hence, bar attachments constitute clinically tested fitting elements for implant-retained and implant-fitted removable superstructures in the toothless upper and lower jaws. No clinical data for the fitting of removable superstructures in the toothless upper jaw for magnets and for ball-head attachments is available. Additionally, the application of so-called locators for the fitting of removable implant superstructures cannot be considered to be based on evidence, according to the currently available data. To date, no results of clinical studies have been presented for this fitting element.

Telescopes as fitting elements for removable superstructures are popular particularly in the German-speaking countries, as they are very hygienic and easy to expand. However, these advantages are offset by the high technical requirements and costs. Clinical studies on the suitability of double crowns as fitting elements in implant prostheses demonstrate that they are generally suitable and they point out the advantage of combining the natural teeth with implants for the fitting of a removable construction, as opposed to attachments.

Fig. 2. Fracture of a bar attachment construction manufactured by casting in the area of the extension.
Fig. 3. Casting of the implants in the pick-up technique with a high strength casting material.
Fig. 4. Tooth arrangement produced on the work model.
Fig. 5. Virtual construction of the bar attachment construction with distal attachments.
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Optimising the manufacturing technology

Despite the high and well-documented survival rates of attachment constructions, the question arises as to whether the strategies can be further optimised in order to avoid defects attributable to the technique. The traditional way of manufacturing attachment constructions is by casting. However, the larger the cast object, the more difficulties arise in terms of porosity and warpage, which increase the risk of mechanical failure and impair the proper fit (Fig. 2).\(^\text{10}\)

Relatively early on, the well-known casting problems led to the establishment of alternative techniques. The application of pre-fabricated implant components, which were then joined by means of soldering or laser welding, was one way to improve the fit. However, with large constructions in particular, this procedure has the disadvantage of very time-consuming manual post-processing. Furthermore, there is the risk that the mechanical ability to cope with pressure may be reduced in the area of the joining point.\(^\text{3}\)

From an economical point of view, it would make sense to use largely bio-compatible material of sufficient mechanical strength for manufacture, such as pure titanium or a Co-Cr alloy. However, the processing of such alternative materials does not provide a sufficiently exact fit with the current casting techniques. In vitro examinations of cast implant superstructures made of non-metallic materials showed gaps of 200 to 300 µm between the superstructure and the implant arrangement.\(^\text{11}\) Compared to this, cast structures made of noble metals featured median gap widths of 40 to 50 µm.\(^\text{12}\) The use of alternative materials therefore requires an alternative processing technology in order to achieve the necessary precision. In the ideal case, the superstructure is cut from a prefabricated solid material in order to safely exclude inhomogeneities.

With this in mind, the manufacture of superstructures with cutting technological means using the computerised numerical control (CNC) process began more than ten years ago. In vitro examinations using this CAM technology demonstrated that the precision achievable in such constructions, with median gap widths between 20 and 30 µm, is better than the accuracy of fit achieved with cast frames made of noble metals.\(^\text{12}\) Modern scanning and software technology allows expansion of this manufacturing principle to virtual construction. Hence, the already well-known process of CNC cutting is supplemented with the option of a purely virtual construction. Several manufacturers offer this technology, for example CompArtis ISUS (DeguDent).

Case presentation

The manufacturing process of an attachment utilising the CompArtis ISUS system is documented below. After exposure of the implants, the next appointment was devoted, as usual, to making a casting with impression material that has a high final hardness and hence guarantees a secure fixing of the casting posts (for example, Impregum, 3M ESPE; Monopren transfer, Kettenbach Dental; Fig. 3).

In the ideal case, the casting appointment would entail the determination of the jaw relations and a casting for the model of the opposing jaw. After that, the work model is manufactured with the help of a removable gingiva mask in the area of the implants. When the first check-bite is taken, a first provisional model can be mounted immediately. Based on this working material, a tooth arrangement is prepared from plastic. It is useful if the information about the colour and the shapes of the teeth is already available during this work step (Fig. 4).

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The tooth arrangement can be tried on at the next appointment and corrected if needed. The exact jaw relations can thus be determined and sufficient information will be collected for the definitive tooth arrangement. At this appointment, the precision of the casting should also be checked with a transfer jig. For this jig, the posts on the work model can be blocked with plastic and a metal reinforcement.
The jig must then fit onto the implants in the mouth without causing tension or shifting around. For the exact determination of the accuracy of the casting fit, it is advisable to perform the Sheffield Test. A screw is mounted and fastened on the post on one side of the distal implant. When fastening the screw, the transfer jig must not lift off the other implants. Furthermore, there must not be any gaps. If the screw can be fastened without making the transfer jig move, it can be concluded that the impression has exactly copied the situation in the mouth. In case of a negative result, a transfer defect can be assumed. In this case, the transfer jig should be separated and all posts should be fastened with screws so that a new impression casting can be taken.

Once an exact impression has been secured and the tooth arrangement has been adjusted, the CAD/CAM manufacture of the superstructure can begin. First, the work model and the tooth arrangement are sent to a Compartis ISUS Planning Centre. There, the virtual construction of the attachment is made according to the specifications of the dentist(s) and dental technician(s). In the present case, a bar attachment construction made of titanium with distal attachments (Preci-Vertix, CEKA) was chosen.

The tooth arrangement determines the space available for the superstructure and alignment towards the chewing area. This information then constitutes the foundation for CAD of the superstructure, the CAD process. For this purpose, special scan posts are initially screwed onto the implants, in order to determine the position of the implants with a first scan. Then, a second scan is done with the wax arrangement, in order to determine the available space and the orientation of the superstructure. Thereafter, the desired superstructure is designed with the help of special software. This constitutes the basis for the manufacture of the superstructure utilising the CNC process (Fig. 5).

Dental technicians and care providers will then receive the construction suggestion of the Compartis ISUS Planning Centre by e-mail with a request for release or for advice regarding changes. As soon as the release is obtained, the manufacture of the attachment begins. The Compartis ISUS system uses modern cutting machines and special cutting strategies and ensures perfect quality of the surfaces, rendering manual post-processing dispensable (Fig. 6).

The dental laboratory can now commence with the fabrication of the secondary construction. In the present case, a secondary structure was initially made by means of electroplating (Solaris, DeguDent) and the plastic matrix for the Preci-Vertix retaining elements was incorporated. Thereafter, a cast tertiary structure was made of a Co-Cr alloy and bonded with the galvanoplastic structure. The superstructure was completed using the existing tooth arrangement (Fig. 7). Several in vitro examinations have proven the excellent accuracy of fit in these CAD/CAM-manufactured constructions (Fig. 8). In a comparison of five different techniques for the manufacture of implant superstructures, the CAD/CAM structures demonstrated a median accuracy of fit of 25 µm, while cast structures had median gap widths of 78 µm.13

However, the advantage of the CAD/CAM technology is not only the highly precise manufacture of superstructures made of pure titanium and Co-Cr alloys, but also its applicability to a broad range of indications. Starting from the scan data, virtual construction allows for a wide range of variations in terms of various forms of superstructures, from the simple round bar to retaining element attachments or to a bridge frame for fixed constructions. With a CAD/CAM system, it is also possible to virtually incorporate active holding elements such as extra-coronal retaining joints, bars and press buttons.

In summary, it can be said that CAD/CAM technology is also ideal for the processing of alternative materials on titanium and non-precious metal basis. It provides the following advantages:

- high mechanical resilience due to homogeneous pore-free materials;
- tension-free fit due to precise CNC-manufacturing technology; and
- suitability for a large width of indications due to individual CAD.

The integration of virtual design supplements the trusted manufacturing technology based on cutting and hence opens up possibilities for new indications for alternative materials in implant prosthodontics.

Editorial note: A complete list of references is available from the publisher.

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**Fig. 8** Good fit with a CAD/CAM-manufactured attachment construction made of pure titanium.

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