The use of computer-aided design/computer-aided manufacturing (CAD/CAM) techniques for fabricating fixed and removable partial dental prostheses has been widely reported. However, less has been published on its use for complete dentures. Initial reports were on the development and proof of concept. In 1994, the use of 3-dimensional (3D) laser lithography was described for the fabrication of complete dentures of photopolymerized composite resin. The outer shells were fabricated by using laser lithography, and the inside was filled with acrylic composite resin. A few years later, a method of duplicating a complete denture using CAD/CAM technology with a computerized numeric control processor for cutting modelling wax was presented. It took approximately 10 years until the next study presented their CAD/CAM-aided method for the fabrication of complete dentures. Virtual flasks were constructed according to the CAD denture casts, and individualized physical flasks were made with a 3D printer. A recent study described a clinical impression procedure for obtaining the morphology of denture bases and the muscular and phonetic positions of the denture teeth. Subsequently, the recorded information was scanned, and the complete denture bases were virtually designed and milled from resin. Nevertheless, clinical reports are scarce. In 2012, a complete denture trial placement method using a rapid prototyping protocol was presented and compared with a conventional trial. A clinical report in 2014 dealt with the CAD/CAM fabrication of complete dentures using the AvaDent system, which allows for making the dentures in 2 clinical visits. The first visit, the impressions, the maxillomandibular relationship record, and the tooth selection are completed, and, at the second visit, the complete dentures are delivered. With this technique the dentures are fabricated without the need for casts, flasking, or other processing methods. Additionally, a review was published which focused on the DENTCA system. The DENTCA system, similar to the AvaDent system, enables denture fabrication in 2 visits, although, a conventional processing technique is necessary. The use of CAD/CAM record bases, made with the AvaDent system, was described for the fabrication of complete dentures.

The conventional method of fabricating complete dentures has been established for over 80 years. It allows for modification of the arrangement of teeth and the evaluation of the treatment steps before delivery. Nonetheless, the conventional method has disadvantages, including the number of patient visits (at least 5 are needed plus the visits after insertion), the high treatment costs associated with these visits and the time- and cost-intensive laboratory work. The inclusion of CAD/CAM technology for the fabrication of complete dentures may reduce cost-intensive laboratory work. The present report of a clinical treatment provides a step-by-step description...
of a CAD/CAM-supported method for fabricating complete dentures.

**TECHNIQUE**

1. In the dental operatory, examine the patient (Fig. 1) and make anatomic impressions (Alginoplast, regular set; Heraeus Kulzer GmbH) of the edentulous maxillary and mandibular arches and send them to the dental laboratory for the fabrication of casts and custom trays.

2. Make definitive impressions (Impregum Penta; 3M ESPE) of the maxilla and mandible and send them to the laboratory for the fabrication of definitive casts, record bases for the maxillomandibular relationship record, and a maxillary baseplate for facebow transfer.

3. Make the facebow and jaw relationship records and determine the smile line, the positions of the canines and the midline, and the position of the anterior teeth for appropriate lip support and optimal esthetics (Fig. 2A). Send the records to the dental laboratory so that the casts can be mounted on an articulator (Fig. 2B) and for the virtual design of the complete dentures with the software (Ceramill Mind/D-Flow; Amann Girrbach).

4. In the dental laboratory, scan the definitive casts separately with an optical scanner (Ceramill Map400; Amann Girrbach) (Fig. 3A,B). Then, scan the casts and the occlusion rim positioned in the transfer stand (Ceramill Transferkit; Amann Girrbach) (Fig. 3C).

5. Import the data into the software to design complete dentures (Ceramill Mind/D-Flow; Amann Girrbach). Mount the scanned maxillary and mandibular casts virtually according to the scanned occlusion rim. For this, superimpose the files digitally and combine them by means of best-fit matching (Fig. 4).

6. Set the occlusal plane with the help of the occlusion rim (Fig. 5A) and analyze the casts with the help of the step-by-step instruction in the software. Mark the anatomic characteristics of the cast surfaces, the position of the first premolars, and the center line with the margin lines (Fig. 5B).
Determine the boundary line for the anterior teeth on the basis of the maxillary record base. With the entered information, the software calculates the common arrangement lines and suggests an applicable set of artificial teeth (Fig. 5C). The deposited artificial teeth are conventionally manufactured teeth made of acrylic resin from different manufacturers and not produced by CAD/CAM technology.

7. Select the preferred artificial teeth and let the software automatically arrange them in their correct position (Fig. 5D).

8. Design the gingival parts of the dentures on the basis of the suggestion of the software with the help of the different tools provided, for example, a virtual wax knife or paint brush (Fig. 5E).

9. Send a preview of the virtual arrangement to the clinician for evaluation.

10.Shorten the basal surfaces of the artificial teeth virtually according to the contour of the alveolar ridges and the minimum denture thickness and provide them with retention for later fixation in the denture bases. Generate the data sets for the denture bases and the tooth sockets.

11. Mill the denture bases with a 5-axis milling machine from a gingiva-colored wax blank (Ceramill D-Wax, Ceramill Motion 2; Amann Girrbach).

12. Modify the conventional denture teeth according to the individual clinical situation. For this, mount them in a special blank/device and mill their basal surfaces corresponding to the prior computation. (Ceramill Motion 2; Amann Girrbach).

13. Wax the adapted denture teeth into the sockets of the wax bases (Fig. 6) and evaluate the completed trial denture in the conventional articulator (Fig. 7). Send the trial denture to the clinician.

14. In the dental office, evaluate the trial dentures in the patient’s mouth. Make adjustments to the arrangement in the conventional way, if necessary.

15. Send the trial dentures to the dental laboratory for their completion by flaking.

16. Deliver the completed dentures (Figs. 8, 9).

DISCUSSION
It has been 20 years since the implementation of CAD/CAM technology in the fabrication of complete dentures was reported. In the last few years, significant advancements have taken place in this field, and the first case reports have been published.12,13

The presented concept of Ceramill Full Denture Workflow incorporates CAD/CAM technology into the workflow of fabricating complete dentures. However, incorporation refers only to the tooth arrangement, the
milling of the wax trial bases, and the modification of the denture teeth so that they can be inserted into the tooth sockets of the bases with wax and without additional grinding.

Compared with the completely conventional technique of fabricating dentures, this procedure has several advantages. Scanning the maxillary and mandibular casts and importing them into the software allows for better detection and visualization of the morphology of the edentulous maxillary and mandibular arches. Virtual sectional views facilitate the identification of anatomic characteristics, and, with the help of a software algorithm, the midlines of the alveolar ridges, for example, can be identified. A further advantage is that the virtual arrangement of the artificial teeth is a reproducible procedure enabling predictable results. With the help of the virtual articulator, static occlusion and the dynamic relation of the dentures are considered during digital arrangement. Also, the digitized maxillary record base can be taken into account, particularly for anterior teeth arrangement. With the correct incisal edge position of the maxillary teeth, ideal lip support can be realized. Moreover, the maxillary record base will be used to establish the plane of occlusion.

Posterior teeth can be arranged according to the occlusal concept of the manufacturer. Thus, an ideal contact situation can be achieved. The arrangement can be performed in significantly less time in comparison with the manual

arrangement. Additionally, the time-consuming procedure of manual waxing is eliminated. The polished surfaces of the denture bases can be easily designed with different anatomic features, for example, stippling and rugae. A preview of the virtual arrangement can be sent to the clinician for approval. If modifications of the tooth arrangement are required, this is possible. Also, for example, for adjustments for esthetic reasons, the arrangement can be superimposed with the digitized record bases.

At the trial placement, minor adjustments of the arrangement can be made in the conventional way. In case of extensive modification, the wax denture base can be milled once more according to the required arrangement, and a second evaluation appointment is possible. Indeed, in the presented patient case, increasing the vertical dimension of occlusion was necessary. The dental technician unscrewed the anterior guide pin and


Figure 7. Milled wax dentures in articulator.

Figure 8. Completed dentures.
remounted the mandibular cast in the articulator with the occlusion rim. As a facebow record had been made, increasing the vertical dimension did not entail errors in the occlusion. The situation was transferred into the virtual articulator, and a new mandibular tooth arrangement was designed with the software.

The virtual design of complete dentures allows for consistent thickness of the bases. The material thickness can be adjusted to the material and kept minimal, allowing for the function and durability of the dentures. Furthermore, a consistent material thickness minimizes deviations in the contact relationships of the teeth, for example, due to polymerization shrinkage, and enables an improved fit to the mucosa, which is important for denture retention.16–18

The dentures may be easily duplicated with the digital data and research in this field is facilitated.10 With the system used here (Ceramill Full Denture Workflow), complete dentures can be digitally completed by milling them from prepolymerized acrylic resin blocks. However, the manufacturer does not currently enable this option because of the risk of remake. The source of error is the manual maxillomandibular relationship record, which is difficult and fault-prone. Development should focus on this field. Also, the problem concerning the durability of the bond between the base and the teeth has not been solved.

Clinical and laboratory research is necessary to validate the new computer-aided treatment procedures for the fabrication of complete dentures.10

SUMMARY

Incorporation of CAD/CAM technology into the design and fabrication of complete dentures helps to simplify laboratory work and standardize complete denture fabrication. Ceramill Full Denture Workflow is a CAD/CAM-based system. With the help of proprietary software, the denture teeth can be arranged and bases designed. Dentures bases are milled from a wax blank, allowing for adjustments after clinical evaluation.

REFERENCES


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