Trial of a CAD/CAM system for fabricating complete dentures

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The purpose of this study was to evaluate the fabrication of a complete denture using a CAD/CAM system. Cone beam CT was used to measure the complete denture and the artificial teeth. After a 3D complete denture image was structured using 3D CAD software, we factored out the artificial teeth and obtained a 3D denture base image. A machining center cut an acrylic resin block, and fabricated an acrylic complete denture base. The artificial teeth were bonded to the cut denture base using resin cement. A 3D digitizer digitized the fabricated acrylic denture. We measured the deviations between the master 3D complete denture image and the 3D data of the fabricated acrylic denture. The average deviations from the master 3D image were 0.50 mm for the occlusal surface.

This present study indicates that it is possible to fabricate a complete denture using a CAD/CAM system.

Keywords: Complete denture, CAD/CAM, Fabricating accuracy

INTRODUCTION

The process of fabricating complete dentures consists of preliminary impressions, construction of a custom tray, definitive impressions, construction of occlusion rims, creating jaw relationship records, arranging prosthetic teeth, try-in, flasking, resin packing and denture delivery. This process with so many steps is associated with certain problems. Methods of denture fabrication have not progressed substantially for the 70 years since polymethyl methacrylate was introduced in 1936. Most importantly, this process is complex and difficult for dentists. Consequently, it requires experienced prosthetists and dental technicians. In addition, it requires many visits of the patient and a large amount of laboratory work. Elderly patients in particular can find the necessity for a lot of hospital visits distressing. Furthermore, acrylic resins do not fulfill all of the requirements for hypothetically ideal denture base materials.

The fabrication of complete dentures using a computer-aided design/computer-aided manufacturing (CAD/CAM) system has the potential to simplify the above process and resolve the associated problems. In recent years, CAD/CAM systems have been successfully introduced into restorative dentistry and maxillofacial technology. Moreover, they have been applied to removable prostheses. For example, Williams et al. fabricated removable partial denture frameworks using CAD/CAM systems. In addition, Kawahata et al. fabricated wax complete dentures using a computerized numerical control (CNC) machining center and Maeda et al. fabricated the shells of complete dentures using CAD/CAM systems. To date, however, no studies have been carried out on the fabrication of complete dentures as definitive prostheses using CAD/CAM systems.

We formulated a method for the fabrication of complete dentures using a CAD/CAM system as follows. First, the dentist reforms the denture worn by the patient. For example, if the denture is not adapted to the mucosa, it requires refitting or relining. Similarly, if it does not have harmonic occlusion, it needs occlusal adjustment or reconstruction of the occlusal surface. Second, dental three-dimensional (3D) cone beam computed tomography (CBCT) scans are performed for the maxillary and mandibular reformed dentures, which maintain the maximal intercuspal position, to obtain 3D morphological data. Third, the 3D data of the reformed denture are used for the only mucosal surface, and the CAD application fabricates the morphological data for the new denture. Upper and lower commercially available artificial teeth are arranged and a polished surface is formed on the CAD application. At this time 3D position of maxillary and mandibular denture base are held on CAD software. The 3D data for the denture base are structured by removing the artificial teeth. Fourth, the CAM technology is applied by using the CNC machining center to cut an acrylic resin block based on the 3D data for the new denture base to fabricate the new complete denture base. Bonding of the artificial teeth, which are selected on the CAD application, to the denture base finishes the new complete denture. In addition, the CNC machining center fabricates the denture by milling. Since this method, which is different from conventional packing, is not limited to particular denture base materials, materials that are more ideal for dentures than acrylic can be used. This method may resolve the current problems and prove useful in the fabrication of complete dentures.

This study focused on the CAD/CAM part of this
system that are designing the denture on CAD software and fabricating the denture the CNC machining center. The purpose was to evaluate the fabrication of complete dentures as definitive prostheses using a CAD/CAM system.

**MATERIALS AND METHODS**

The one complete denture and the artificial teeth (Real Crown and Endura Posterio; Shofu, Kyoto, Japan) were scanned separately using a Dental 3D CBCT System (Fine Cube; Yoshida, Tokyo, Japan), and a DICOM viewer (OsiriX; The OsiriX Foundation, Geneva, Switzerland) processed the 3D morphological STL format data for the complete denture and the artificial teeth (Fig. 1). After the 3D CAD software (CATIA V5R19; Dassault Systemes, Velizy-Villacoublay, France) created a new 3D complete denture image based on the 3D data for the complete denture and the artificial teeth (Fig. 2), the artificial teeth were factored out using Boolean logic and a 3D denture base image was obtained (Fig. 3). The 3D CAM software (Mastercam; CNC Software Inc., Tolland, CT) programmed the cutter path based on the 3D denture base image. A five-axis CNC machining center (Variaxis 200; Yamazaki Mazak, Aichi, Japan) cut an acrylic resin block based on the cutter path, and fabricated one acrylic complete denture base (Fig. 4). This cutting time was about 150 minutes. The artificial teeth were bonded to the cut denture base using a resin cement (Super Bond; Sun Medical, Shiga, Japan) (Fig. 5). A 3D digitizer (Atos; Gom International AG, Widen, Germany), which is a flexible optical measuring machine based on the principle of triangulation, digitized the fabricated acrylic denture. The deviations between the

![Fig. 1](image1.png) 3D morphological data for the complete denture and the artificial teeth.

![Fig. 2](image2.png) 3D data for the new complete denture.

![Fig. 3](image3.png) 3D data for the new complete denture base.

![Fig. 4](image4.png) Acrylic complete denture base.

![Fig. 5](image5.png) New complete denture.
master 3D complete denture image and the 3D data for the fabricated acrylic denture were measured at all nodes of polygons by using interchanging 3D measuring software (Atos Viewer; Gom International AG, Widen, Germany), which superimposed two 3D-STL data. The averages of the nodes were calculated for mucosal, polished and occlusal surface respectively. All the scanning and digitize was performed one time because this measuring had high reliability for static objects in pilot study.

RESULTS

The data for the fabrication accuracy are shown in Figures 6–8. There was good accuracy for the buccal polished surface (Figs. 6 and 7). The average deviations from the master 3D data were about 0.10 mm for this surface. However, the occlusal surface was fabricated with lower accuracy. In the artificial teeth part, the maximum deviation was about 0.88 mm and the average deviation was 0.50 mm. There was also good accuracy for the mucosal surface (Fig. 8). The average deviation from the master 3D data was about 0.10 mm for this surface.

DISCUSSION

In this new method for the fabrication of complete dentures using a CAD/CAM system, a Dental 3D CBCT System was used to digitize the dentures. The reasons for selecting the Dental 3D CBCT System are as follows. The CBCT System is equipped with the shortest imaging times and is easy to operate compared with other digitizers. In this scanning method, only refined dentures that maintain the maximal intercuspal position are scanned quickly. Therefore, not only the 3D morphological data of the denture space but also the jaw registration are obtained without exposing the human body to radiation. Furthermore, the CBCT System will generally become widely used in dental hospitals and dental offices in the future.

A five-axis CNC machining center was used to fabricate the complete denture. There are two types of manufacturing methods based on 3D data. One method is rapid prototyping, as typified by selective laser sintering, stereolithography and 3D printing. The other method is cutting work using a machining center. The properties of the definitive prosthesis fabricated by the five-axis CNC machining center are more suitable for a denture base compared with rapid prototyping at the present time.

The artificial teeth and denture base are equipped with different colors and properties. The artificial teeth need high abrasion resistance and an aesthetic appearance. It is difficult to cut the artificial teeth from a single property block. Thus, only the denture base was fabricated by cutting, and commercially available artificial teeth were adhered to the denture base. In this step, a resin cement was used as an adhesive. Currently, special adhesives with higher adhesive properties than resin cement are being developed.

Fig. 6 Results of the accuracy measurements: front view.

Fig. 7 Results of the accuracy measurements: occlusal surface.

Fig. 8 Results of the accuracy measurements: mucosal surface.

A complete denture was designed on a computer, followed by digitization of the fabricated denture and measurements of the fabrication accuracy. CAD/CAM systems have been applied to quality control in the industrial world, and are well suited for measuring fabrication accuracy. Large surfaces like the polished
and mucosal surfaces showed good accuracy. In these parts, the deviations ranged from 0 to 0.10 mm. These results indicate that the machining center had sufficient cutting accuracy and cut the block definitely based on the 3D data.

In the artificial teeth part, some points showed large deviations. These large deviations were attributable to the fact that the artificial teeth and their sockets on the denture base could have different sizes. This situation arises for two reasons. The first is shrinkage of the 3D data when the CT scan is performed. Ballrick and Baumgaertel\(^{11,12}\) reported that CBCT had a tendency to underestimate the actual values of each measurement. This underestimation occurred in 94.4% of the measurements and the differences were less than 0.1 mm. The second is the smoothing that occurs when 3D images are processed on the DICOM viewer. Because the DICOM data scanned from CT images are slice data, the processed 3D image has a stepped surface. Accordingly, when the DICOM viewer processes the 3D data, a smoothing function is used. Surface smoothing can make the geometry smaller by up to 5%\(^{13}\). Based on the reasons discussed above, although mucosal surfaces showed good accuracy, the 3D data of the artificial teeth could be smaller than the real artificial teeth. Therefore the artificial teeth did not fit into their sockets on the denture base. To resolve the above problems, when the DICOM viewer processes the 3D data, consideration of the amount of shrinkage or processing without shrinkage would lead to better accuracy.

The present study indicates that complete dentures can be fabricated using CAD/CAM systems in the future. This new method, which breaks from the conventional method, may lead to simplification of the laboratory work, shorten chair times and maintain the quality of treatment. In addition, this molding method can apply materials that are equipped with innovative properties. Further studies involving the fabrication of complete dentures using gingival color resin under conditions that are closer to clinical circumstances and measurements of the fabrication accuracy are planned.

**CONCLUSIONS**

The present study indicates that it is possible to fabricate a complete denture using CAD/CAM systems. However, since the slight difference between artificial teeth and sockets on denture base may cause large deviations, further improvements are needed in processing the 3D data.

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**REFERENCES**