AMERICAN COLLEGE OF PROSTHODONTISTS
Your smile. Our specialty.

Fabricating Complete Dentures with CAD/CAM and RP Technologies

Mehmet Selim Bilgin, DDS, PhD,[1] Ali Erdem, DDS, PhD,[1] Osman Sami Aglarci, DDS, PhD,[2] & Erhan Dilber, DDS, PhD[1]

[1]Department of Prosthodontics, Faculty of Dentistry, Sifa University, Izmir, Turkey
[2]Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Sifa University, Izmir, Turkey

The article is associated with the American College of Prosthodontists' journal-based continuing education program. It is accompanied by an online continuing education activity worth 1 credit. Please visit www.wileyhealthlearning.com/jopr to complete the activity and earn credit.

Keywords
Rapid prototyping; 3D printing; complete denture; digital; CAD/CAM; tooth alignment.

Correspondence
Mehmet Selim Bilgin, Sifa University, Faculty of Dentistry, Department of Prosthodontics Mansuroğlu Mah. 293/1 No:14, 35100, Bayrakli, Izmir, Turkey.
E-mail: mselimbilgin@gmail.com

Conflict of interest: None declared

Accepted January 4, 2015

doi: 10.1111/jopr.12302

Abstract

Two techological approaches for fabricating dentures; computer-aided design and computer-aided manufacturing (CAD/CAM) and rapid prototyping (RP), are combined with the conventional techniques of impression and jaw relation recording to determine their feasibility and applicability. Maxillary and mandibular edentulous jaw models were produced using silicone molds. After obtaining a gypsum working model, acrylic bases were crafted, and occlusal rims for each model were fabricated with previously determined standard vertical and centric relationships. The maxillary and mandibular relationships were recorded with guides. The occlusal rims were then scanned with a digital scanner. The alignment of the maxillary and mandibular teeth was verified. The teeth in each arch were fabricated in one piece, or set, either by CAM or RP. Conventional waxing and flasking was then performed for both methods. These techniques obviate a practitioner's need for technicians during design and provide the patient with an opportunity to participate in esthetic design with the dentist. In addition, CAD/CAM and RP reduce chair time; however, the materials and techniques need further improvements. Both CAD/CAM and RP techniques seem promising for reducing chair time and allowing the patient to participate in esthetics design. Furthermore, the one-set aligned artificial tooth design may increase the acrylic's durability.

Seventy-seven years ago, a new age for complete dentures was ushered in with the clinical evaluation of methyl methacrylate (MMA). Within a decade, MMA was the preferred material for 95% of the dentures manufactured because it fulfilled the requirements for an ideal base material.[1] Furthermore, MMA is used as a major component in artificial tooth sets, which consist of several materials such as poly(methyl methacrylate) (PMMA) and various ceramics and composites. Since 1940, acrylic teeth have been used in the fabrication of complete dentures. Acrylic teeth are preferred for their price and esthetics and because they chemically bond to an acrylic denture base.[2] In contrast, ceramics do not bond chemically to acrylic; however, they are resistant to surface wear, and porcelain teeth are believed to transmit forces to bone directly.[3]

For these reasons, manufacturers were motivated to develop alternative denture materials by factoring in esthetics, bonding, biocompatibility, and stress distribution.[4] With the development of new technologies, patients are required to spend less time in clinics and make fewer visits. Consequently, even chairside and other laboratory personnel work fewer hours.[5,6]

Computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies have been used for single-visit restorative treatments. Previous studies have shown how accurate results can be obtained through digital impression techniques.[7,8] According to the findings of more recent studies, mistakes that previously occurred during the clinical and laboratory phases can now be prevented, owing to the extreme accuracy afforded by digital impression devices,[9,10] and the repetitions required for conventional impression techniques can now be avoided. Furthermore, obtaining direct digital impressions from edentulous patients is a topic of much discussion because of the displaceability of soft tissues.[11] An advantage of virtual design is that any shape can be digitally prototyped. Rapid prototyping (RP) is an innovative technique currently employed in dentistry. With the appropriate design software and hardware, it is possible to arrange the dentition, occlusion, shape, angulations, and even the flange itself with different colors.[12] Therefore, in the near future, complete dentures are expected to be commercially produced by medical informatics institutions rather than laboratory technicians.

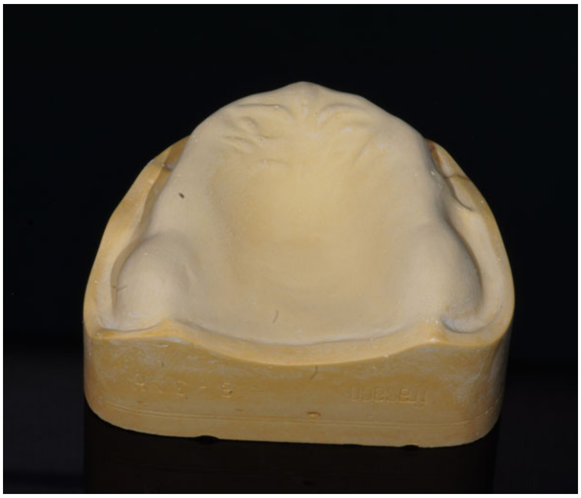

Figure 1 Maxillary working model.

Figure 2 Maxillary working model with acrylic base and wax rim.

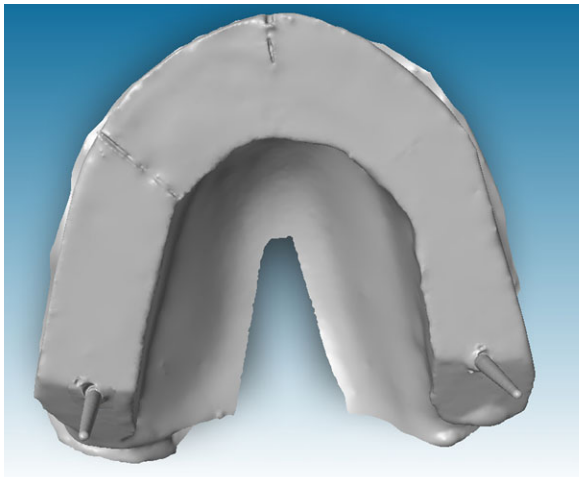

Figure 3 Digitally scanned maxillary wax rim and acrylic base.

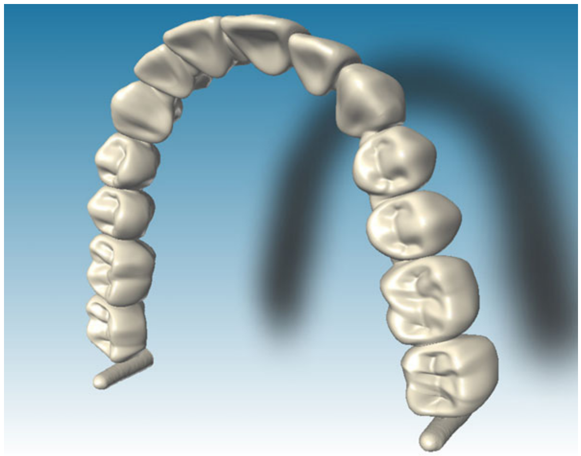

Figure 4 Designed maxillary teeth.

Experimental technique

In our experimental laboratory procedure, a combination of conventional techniques with two approaches, CAD/CAM and RP, was used to fabricate complete dentures. Maxillary and mandibular edentulous jaw models were made using silicone molds (B-3 NHG; Frasaco GmbH, Tettnang, Germany). After fabricating a gypsum (Sherapremium; Shera Werkstoff Technologie GmbH, Lemförde, Germany) working model (Fig 1), acrylic (Sherapress, Shera Werkstoff Technologie GmbH) bases were crafted, and wax rims (Fig 2) for each model were fabricated. A bite registration block with edentulous maxillary and mandibular models was used for mounting the working models on the articulator to provide standardized vertical and centric relationships. With the guidance of the plaster model's anatomic landmark (labial frenulum, corners of the arch), midline and canine zones were marked on the occlusal and labial surfaces of the wax rims. The smiling zone was adjusted according to the height of the bite registration blocks of the upper rim. A one-set aligned artificial tooth (1SA) system was designed and manufactured as one piece for the maxillary and mandibular arch using CAD/CAM and RP, respectively.

CAD/CAM

The occlusal rims were scanned with a digital scanner (D810; 3Shape, Copenhagen, Denmark) to obtain 3D images of the rims and base (Fig 3) together with the guides as the midline, maxillary canine locations, and smiling zone. The scanned images of the rims are important for the curve of the arches as well as the height and width of the artificial teeth. In addition to these guides, the locations of the rims in the artificial design are required to ensure that the rims are a support for soft tissues such as lips and cheeks. According to the fabricated guides and occlusal rim shape, the design of the 1SA of the maxillary and mandibular arches (Fig 4) and occlusion was digitally completed using a computer (Precision T5400 workstation; Dell,

Figure 5 1SA CAD/CAM maxillary and mandibular models.

Figure 6 1SA CAD/CAM with wax modelling.

Figure 7 Definitive prostehesis with 1SA CAD/CAM.

Round Rock, TX) using dwos software (Dental Wings Inc., Montreal, Canada). The monochromatic PMMA block (Tempo Cad; On-Dent Ltd, Izmir, Turkey) used for the temporary fixed restoration was milled (Fig 5). The 1SA artificial teeth were embedded in wax rims, and waxing and flasking procedures were fabricated using the conventional methods with metal flasks to obtain the definitive prosthesis (Figs 6, 7).

Figure 8 1SA RP maxillary and mandibular models.

Figure 9 1SA RP with wax modeling.

Figure 10 Definitive prosthesis with 1SA RP.

Rapid prototype (RP)

The 1SA digital design was sent to EnvisionTEC Laboratories for manufacturing with an RP machine (P4 DDP Mini; EnvisionTEC GmbH, Gladbeck, Germany) using an A2 shade light-cured, micro-hybrid, nano-filled resin (E-Dent 100; EnvisionTEC GmbH). Then the resins were photo-polymerized on a voxel-by-voxel basis (volumetric pixel) of the liquid resin. It took 76 minutes to build the design with a 50-μm-thick layer. The light power was 180 mW/dm^2, and the number of flashes was 6 $\times$ 1000. After achieving the maxillary and mandibular

1SA design (Fig 8), wax (Cavex Set Up Wax, Cavex, Haarlem, The Netherlands) modeling was performed. Flasking procedures were fabricated according to the conventional methods with metal flasks, and the definitive prosthesis was obtained similar to the CAD/CAM technique (Figs 9, 10).

Discussion

Since 3D scanners were introduced to dentistry, the accuracy of the obtained images has been a subject of much discussion and research. Several studies have been conducted to measure the accuracy of these devices, and the measurement of working models with calipers is assumed to be the standard. These measurements have been compared with digital measurements.[7-10,13]

Inokoshi et al[12] fabricated trial dentures with RP. According to the results of a deviation analysis, RP offers high processing accuracy compared to conventional wax dentures. The mucosa has a displaceability of approximately 0.14 to 0.34 mm. Compensation for these deviations can be performed clinically. A trial insertion appointment can still be included to advance the quality of denture fabrication with RP. Even though the devices and techniques are promising, it is necessary to acquire impressions in the same manner as in the conventional method, that is, taken in impression compound with custom trays.

In the near future, cone-beam computed tomography (CBCT) or magnetic resonance imaging (MRI) could be used instead of taking impressions or scanning for complete dentures with some apparatus; however, the depth of the sulcus and the displaceability of removable soft tissues are problems that remain unsolved. Infante et al[6] studied a maxillary and mandibular anatomic measuring device (Avadent) used for recording the vertical and centric relationships of the upper and lower jaws, and they found it challenging to record the jaw relationships because the system does not provide all occlusion schemes.

RP and CAD/CAM systems will reduce chair time for patients. Although some systems build the entire structure, failures will require remanufacturing of the prosthesis at a high cost. In our study, 1SA has the advantage of avoiding occlusal vertical relationship and centric relation errors due to the technician's potential manipulation errors while transferring models to the articulator and arranging teeth manually. Therefore the design and manipulation phases are extracted from the technician's process in the RP and the CAD/CAM methods. In addition, it is possible to consider the personal choices of patients, and dentists can directly relate their knowledge of occlusion and esthetics to the design without the assistance of a laboratory technician.[12] As is widely known, the three essential variables in the selection of complete dentures are composition, color, and shape. The denture tooth selection process may be eliminated chairside and provided by the 1SA system digitally.

It is also possible that 1SA may provide extra strength to the denture due to the one-piece construction when compared to individually placed denture teeth. A limitation for complete dentures fabricated with RP is the manufacturing expense, which is still high for clinics. The high price is consequently passed on to the patients. Furthermore, the safety of these RP acrylic materials is still being tested, and these materials are being assessed for long-term use.

Conclusion

The proposed and tested CAD/CAM and RP techniques obviate a practitioner's need for technicians during design and provide the patient with an opportunity to participate in esthetic design with the dentist. In addition, CAD/CAM and RP reduce chair time. Although further improvements in techniques and materials are needed regarding the production, toxicity, and machinery, the final product demonstrates that denture fabrication can be accomplished with self-designed esthetics, occlusion, and potentially increased durability using 1SA, especially with single complete dentures opposing natural dentition when the dentures are fabricated using RP or CAD/CAM.

References

1. Murray MD, Darvell BW: The evolution of the complete denture base. Theories of complete denture retention–a review. Part 1. Aust Dent J 1993;38:216-219
2. Thean HP, Chew CL, Goh KI: Shear bond strength of denture teeth to base: a comparative study. Dent Dig 1996;27:425-428
3. Sipahi C, Ozcan M, Piskin B: Effect of physicochemical surface treatments on the bond strength and adhesion of porcelain denture teeth to heat-polymerized acrylic resin denture base material. J Adhes 2012;88:200-212
4. Rickman LJ, Padipatvuthikul P, Satterthwaite JD: Contemporary denture base resins: Part 2. Dent Update 2012;39:176-178, 80-82, 84 passim
5. Kanazawa M, Inokoshi M, Minakuchi S, et al: Trial of a CAD/CAM system for fabricating complete dentures. Dent Mater J 2011;30:93-96
6. Infante L, Yilmaz B, McGlumphy E, et al: Fabricating complete dentures with CAD/CAM technology. J Prosthet Dent 2014;111:351-355
7. Sousa MV, Vasconcelos EC, Janson G, et al: Accuracy and reproducibility of 3-dimensional digital model measurements. Am J Orthod Dentofacial Orthop 2012;142:269-273
8. Alcan T, Ceylanoğlu C, Baysal B: The relationship between digital model accuracy and time dependent deformation of alginate impressions. Angle Orthod 2009;79:30-36
9. Dincel M, Gumus HO, Buyuk SK, et al: The evaluation of the accuracy of the 3 dimensional digital model measurements. J Dent Fac Atatürk Uni 2013;21:366-370
10. Yuan FS, Sun YC, Wang Y, et al: Accuracy evaluation of a new three-dimensional reproduction method of edentulous dental casts, and wax occlusion rims with jaw relation. Int J Oral Sci 2013;5:155-161
11. Hobrink J, Zarb GA, Bolender CL, et al: Prosthodontic Treatment for Edentulous Patients: Complete Dentures and Implant-Supported Prostheses (ed 12). St. Louis, Mosby, 2004, pp. 298-328
12. Inokoshi M, Kanazawa M, Minakuchi S: Evaluation of a complete denture trial method applying rapid prototyping. Dent Mater J 2012;31:40-46
13. Gümüş HÖ, Dinçel M, Büyük SK, et al: The effect of pouring time on the dimensional stability of casts made from conventional and extended-pour irreversible hydrocolloids by 3D modelling. J Dent Sci 2014 DOI: 10.1016/j.jds.2014.05.003