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An update on CAD/CAM removable complete dentures: A review on different techniques and available CAD/CAM denture systems

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Abstract

(Times New Roman, 10, Bold) This article describes the different techniques and CAD/ CAM denture systems that are available. The fabrication of removable complete dentures by CAD/ CAM systems reduces chair side time and also number of appointments. If the dentures are lost or broken, it can be refabricated from the records saved digitally. The different CAD/ CAM denture systems evaluated in this article are AVADENT, the Whole You Nexteeth system, Ceramill Full Denture system, Baltic denture system and Wieland denture system and VITA VIONIC system. These systems differ in the number of appointments and the try in options provided by each of them.

Keywords: CAD/CAM systems, CAD/CAM dentures, removable complete denture

1. Introduction

With the success of Computer-aided design/computer-aided manufacturing (CAD/CAM) in implant and fixed prosthodontics, CAD/CAM complete dentures were set in motion. The use of CAD/CAM technology reduces the number of dental technicians required, with extensive experience and expertise with traditional fabrication processes ^[1]. CAD/CAM dentures offer some important advantages like reduction of residual monomer, improved physical properties of the acrylic resin base, reduction in polymerization shrinkage, reducing the number of patient visits, and adhesion of *Candida albicans* to the denture base ^[2, 3]. Compared to the conventionally processed dentures.

CAD/CAM has emerged as a new approach for the design and fabrication of complete dentures. The clinical data recorded from the patient along with the design of the manufactured prostheses is archived digitally. If the prosthesis breaks or is lost, a spare or new prosthesis can be made without clinical appointments using the archived data. The use of CAD/ CAM was limited in the production of complete dentures due to the lack of suitable CAD software until recently.

The first article regarding the concept of CAD/CAM complete dentures originated in Japan which described the fabrication of complete dentures using CAD-CAM system. Maeda *et al.* ^[4] presented the idea of applying rapid prototyping (printing) technology in the fabrication of complete dentures. Kawahata *et al.* ^[5] introduced a different method of using computerized numerical control (CNC) machines to digitally duplicate existing complete dentures and then identical prostheses are milled. Since then, several investigators have contributed to improvements in this field, ranging from digital tooth arrangement to incorporating cone beam computed tomography (CBCT) to scanning and fabricating complete dentures through either rapid prototyping technology or CNC milling.

Based on the terminology available in the dental literature, complete dentures fabricated with the use of a computer for designing and/or manufacturing are referred to as either digital or CAD-CAM dentures. CAD-CAM dentures can be either digitally designed (CAD) or digitally fabricated (CAD/CAM) complete dentures. For consistency and uniformity, we have used the term computer-engineered complete denture (CECD), which includes digital and CAD-CAM complete dentures ^[6].

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The denture base is milled from preformed acrylic resin blocks [7] that were previously polymerized under great heat and pressure [8] resulting in a highly condensed resin that is assumed to release less monomer [8] and to have fewer microporosities [8]. Porosities are one of the factors that give rise to microbial colonization of the denture base [9]. Which is often high, particularly among older or dependent patients [10]. Among milled denture bases [11, 12], the congruence between denture base and denture-bearing tissues is higher as there is no issue of polymerization shrinkage [8]. This results in better denture fit [11, 12] and thereby, a lower frequency of traumatic ulcers [13], common issues with removable dentures [14]. The digital dentures do not undergo polymerization shrinkage and hence the digitally designed occlusion might be better balanced and may show higher chewing effectiveness and also makes remounting unnecessary.

The most emanate advantage for dentists and patients is probably the reduced clinical chair time and number of visits [9, 11-13] required for most CAD/CAM denture systems. Different manufacturers have developed different protocols and choosing the right denture system is crucial. Few reports on CAD/CAM fabricated dentures have been published, and those few studies refer mainly to two systems (AvaDent Digital Dentures, Dentca) [7, 8, 11-13].

With the recent interest in removable complete dentures manufactured using computer-assisted technology, it is important to integrate existing scientific data to promote accuracy and consistency in future scientific reporting. Therefore, the purpose of this review is to evaluate the data focusing on the various techniques and the different available CAD/CAM denture systems.

2. Techniques for manufacturing CAD/ CAM removable complete dentures

2.1 AVADENT technique

The AvaDent system helps in the fabrication of two types of denture using subtractive manufacturing.

- 1) A milled denture base (AvaDent XCL) in which the teeth and base are a single unit
 - a. XCL-1 – single layer tooth that has a dentin core
 - b. XCL-2 – multiple layered tooth that has a dentin and enamel core with natural morphology
- 2) Milled denture base with bonded denture teeth

The AvaDent system also helps in fabrication of immediate complete dentures, record bases, maxillofacial prostheses and single-arch complete dentures.

Clinical procedures

It can be completed in two/three appointments with the addition of denture try-in.

Appointment one

The definitive impression and jaw relation records can be made using various methods and materials.

1. Existing dentures used as trays after duplication for making impression and recording interocclusal relation.
2. Stock thermoplastic dentures with teeth used as impression trays for making impression along with interocclusal record
3. Conventional method in which separate maxillary and mandibular impressions are made using non aqueous elastomeric impression material
4. Using an Anatomical Measurement Device (AMD) clinical records are made with maxillary and mandibular partial arch trays.

The AMD comprises of maxillary tray with a centrally located adjustable stylus (for Gothic arch tracing) along with an adjustable lip support flange and a mandibular tray which consists of a flat occlusal tracing plate. To help with the alignment of the maxillary teeth with the interpupillary line, an additional occlusal plane orientation ruler can be attached to into the maxillary AMD.

The maxillary AMD is coated with adhesive, filled with AvaDent registration material and then seated in the mouth such that it records the morphology of the maxillary arch and also stabilizes the tray. Then the mandibular AMD is coated with adhesive, filled with Ava Dent registration material and then seated in the mouth such that they are fairly parallel to each other and the maxillary stylus should be touching the mandibular tracing plate.

The occlusal vertical dimension is identified either by assessing the vertical dimension when the existing dentures are at occlusion or by conventional methods. The adjustable screw is used to move the central bearing pin up or down till it contacts the mandibular tracing plate at the appropriate vertical dimension. Then the upper lip support flange in the maxillary AMD is adjusted so as to obtain an adequate lip support. The Gothic arch tracing is made by having the patient make protrusive and lateral mandibular movements. The stylus on the maxillary tray scribes lines on the mandibular flat tracing plate. An arrow point is obtained in which the apex of the arrow denotes the centric relation (CR) position. A small depression is made using round acrylic resin bur in the tracing plate, which coincides with the tip diameter of the stylus and the apex of the Gothic arch arrow. The mandible is then maneuvered to a position where the stylus engages the depression so as to maintain the centric relation position. Next step is to insert the Ava Dent ruler in the maxillary AMD and orient it in such a way that it is parallel to the interpupillary line and the angle is noted for assisting the manufacturer in orienting it in the laboratory. The midline, smile line is marked and tooth size and position of the pink denture base around the necks of the teeth are selected from the teeth selection mold tabs.

The mandible is guided to the CR position by the stylus engaging the depression in the tracing plate. An interocclusal registration material is injected into the space between the maxillary and mandibular AMD trays to secure it in place. The final impression and the connected AMD trays are disinfected and sent to the manufacturer for further processing. They are laser scanned and dentures are designed virtually. The denture base is milled with recesses in which the denture teeth accurately fit. The denture teeth are bonded using proper bonding mechanism.

Additional appointment (Trial denture)

Try in dentures are necessary to evaluate and approve the design of the denture before the final denture is milled.

Two types of try in dentures are available:

1. Advanced-try in denture: milled base with recesses into which denture teeth are secured with wax
2. All-resin milled bio functional trial denture: available in multiple tooth shades

The final dentures with the necessary corrections, if needed, are sent back to the manufacturer for the final denture fabrication.

Appointment two

The placement procedures are the same as that of the

conventional dentures. Occlusal adjustments are done intraorally or by using lab remounts.

Drawbacks: Additional training is recommended. Adjustments are done in the same procedure and this becomes stressful for the clinician.

2.2 The Whole You Nexteeth system (Formerly DENTCA)

Used for the fabrication of denture trays and designing of dentures. The CAD/CAM dentures are made with the help of DENTCA, Inc, and Whole You, Inc, a sister company of DENTCA, Inc. The CAD part is completed by the DENTCA, Inc, and CAM part is completed by Whole You, Inc.

Complete dentures are fabricated in two ways

1. Trial denture is printed and verified in the patient's mouth and then traditionally processed using a custom 3D printed flask.
2. Denture base printed by a 3D printer and denture teeth are bonded to printed base.

The DENTCA trays consist of two pieces with detachable posterior segments. These trays are used for both definitive impressions and also for the jaw relation records. For recording the jaw relation, complete arch impression is sectioned, posterior segments are removed and a gothic arch device is attached to it.

Appointment one

Functional impressions are made using these trays and silicone impression material. Using a surgical blade, a single incision line is produced on the maxillary and mandibular impressions to detach the posterior segment from the anterior segments.

Here, the stylus is attached to the lingual surface of the mandibular tray whereas the tracing plate is attached to the maxillary tray, when compared to the AMD trays in AvaDent denture system. The anterior parts of the impressions are inserted into the mouth and the occlusal vertical dimension determined and adjustments made, if necessary. The Gothic arch tracing is made by having the patient make protrusive and lateral mandibular movements. The stylus on the mandibular tray scribes lines on the maxillary flat tracing plate. An arrow point is obtained in which the apex of the arrow denotes the centric relation (CR) position. A small depression is made using round acrylic resin bur in the tracing plate, which coincides with the tip diameter of the stylus and the apex of the Gothic arch arrow.

The mandible is then maneuvered to a position where the stylus engages the depression so as to maintain the centric relation position in order to stabilize it while recording the interocclusal registration. Interocclusal registration record material is injected in the space between the maxillary and mandibular trays. In addition, a lip ruler is provided in this system to measure the length of the maxillary lip (between the incisive papilla and inferior border of upper lip).

The trays and the impressions are then disinfected and sent to the laboratory for the final denture fabrication. They are scanned to produce the maxillary and mandibular virtual edentulous ridges using special computer software. The dentures are designed virtually and the data is transferred to the 3-D laser lithography machine that fabricates trial dentures using a rapid prototyping process, unlike the AvaDent system which uses subtractive manufacturing.

Additional appointment (Trial denture)

The stereolithographic trial denture helps in evaluating and

approving the design of the denture before the final denture is fabricated. The final dentures with the necessary corrections, if needed, are sent back to the manufacturer for the final denture fabrication.

Appointment two

The placement procedures are the same as that of the conventional dentures. Occlusal adjustments are done intraorally or by using lab remounts.

Drawbacks: The option to individualize the dentures is limited.

2.3 Ceramill Full Denture system

The dentures fabricated by the Ceramill full denture system are design by the laboratory technician. The digital workflow of the system begins in the laboratory. It helps in tooth arrangement, 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.

Appointment one

The definitive impressions of the maxillary and mandibular arches are made and sent to the laboratory for the fabrication of definitive casts, records bases for the maxillomandibular relationship record, and a maxillary baseplate for facebow transfer. The record bases are used to record the VDO (vertical dimension at occlusion), midline, smile line, canine positions and facebow transfer.

Appointment two

The facebow and jaw relationship records are made. The smile line, positions of the canines, the midline and the position of anterior teeth for appropriate lip support and optimal esthetics are determined.

These records are then sent to the laboratory. The casts are then mounted on an articulator and the mounted casts along with the occlusal rims are scanned using optical 3D scanner (Ceramill Map400, Amann Girrbach AG). The casts are scanned separately also. This helps in obtaining virtual casts and also transferring the position of casts to the design software (Ceramill Mind/ D-Flow; Amann Girrbach).

The virtual designing consists of identifying anatomical landmarks, tooth arrangement, selection of applicable set of artificial teeth. The designed dentures are sent to the clinician for approval. Once it is approved, the maxillary and mandibular bases are milled from a gingiva- colored wax blank (Ceramill D-Wax, Ceramill Motion 2; Amann Girrbach). Based on the clinical situation, the denture teeth can be modified by milling the basal surfaces of the teeth. The modified denture teeth are then waxed in position on the wax bases. The trial denture is then sent to the clinician.

Appointment three

The trial dentures are evaluated in the patient's mouth for esthetic, phonetics, and function. Necessary adjustments are made and then sent to the laboratory for fabrication of the final dentures.

The dentures are fabricated by conventional technique.

Appointment four

The placement procedures are the same as that of the conventional dentures. Occlusal adjustments are done intraorally or by using lab remounts.

2.4 Baltic denture system (Merz Dental)

This denture system is based on the principle of adjustment of bite rims containing preformed occlusal arches (BD keys) by relining until the dental arches are placed in the anatomically correct 3D position. The procedure is complete in just two appointments leading to high patient satisfaction.

The BDKEY set components include maxillary and mandibular adjustable record bases with teeth, available in 8 different configurations (S, M, and L, with different palatal widths and tooth size).

Appointment one

The definitive impressions are made by adjusting the BDKEY trays inside the mouth. The facial midline, interpupillary line and the Camper lines are registered using a facebow that is attached to the maxillary tray. It also helps in the transfer of functional and esthetic components from the patient to the designing software. BDKEY Lock, a special device helps in recording the jaw relation. The evaluation of esthetics, overall lip support, tooth alignment and interocclusal space is possible due to the teeth present on the trays. These also serve as try in dentures.

The records that are sent to the laboratory are scanned and virtual designing of the dentures is done by BDCreator software. After design approval, the dentures are milled from milling blanks made of Polymethyl methacrylate (PMMA)

Appointment two

The placement procedures are the same as that of the conventional dentures. Occlusal adjustments are done intraorally or by using lab remounts.

2.5 Wieland denture system (Wieland dental + Technik Ivoclar Vivadent)

This system is composed of a five axis-milling machine combined with a laboratory scanner and design software (3shape™). System protocol consists of three appointments if the try in appointment is excluded.

Appointment one

Anatomical impressions of the maxillary and mandibular arches are made. In addition, a specific device called the Centric Tray (Ivoclar Vivadent) is used to record the vertical dimension and provisional jaw relation. A special instrument called the UTS CAD transfer arch is used to determine the occlusal plane temporarily. The UTS CAD helps in measuring the Camper line and interpupillary line. The preliminary impressions, centric tray and the Camper line and interpupillary measurements are sent to the laboratory technician.

The records are scanned and data transferred to the software for virtually designing the dentures. Customized impression trays with integrated occlusion plates are designed with a uniform offset (for impression material) and a recess to allow stabilization of Gnathometer CAD (Ivoclar Vivadent). This Gnathometer CAD helps in Gothic arch tracing and recording CR.

Appointment two

Functional impressions are made with milled individual impression trays. The occlusal plane is verified by using the UTS CAD. The Gnathometer CAD is attached to the customized trays. The patient's midline, smile line, and canine-to-canine lines are established. VDO and CR are

recorded using conventional techniques.

The functional impression and records are scanned and data transferred to the software. Occlusal plane determined, denture teeth selected and virtual tooth setup is done. Try in dentures fabricated from PMMA bloc.

Appointment three

Try in dentures are inserted in the patient's mouth to evaluate the esthetics, function and phonetics. If necessary, corrections are made and final dentures fabricated.

Appointment four

The placement procedures are the same as that of the conventional dentures. Occlusal adjustments are done intraorally or by using lab remounts.

Drawbacks: It doesn't allow the fabrication of individual full arch dentures.

2.6 Vita Vionic system

This system provides materials for open CAD/ CAM systems. The digital design and fabrication can be facilitated by non-system inherent scanners, software and milling machines. The system is flexible and can adjust to the protocol familiar with the user. Thus, conventional denture fabrication protocol with five steps as well as a reduced session protocol (anatomical impression, functional impression plus determination of vertical and maxillomandibular jaw relation, denture placement) can be applied. The impressions, casts or registrations are recorded conventionally and then digitalized. If the try in dentures are needed, they can be milled from wax discs provided by VITA.

Drawbacks: Digitalization process is not customized for each system.



Fig 1: Maxillary and mandibular trays of the Anatomic Measuring Device (AMD)



Fig 2: AMD at the exact vertical dimension of occlusion with a centric relation record



Fig 3: Digital preview of the designed complete dentures, ready for the clinician's approval



Fig 7: Interoclusal records made in centric relation.



Fig 4: Milled complete dentures at the time of placement.

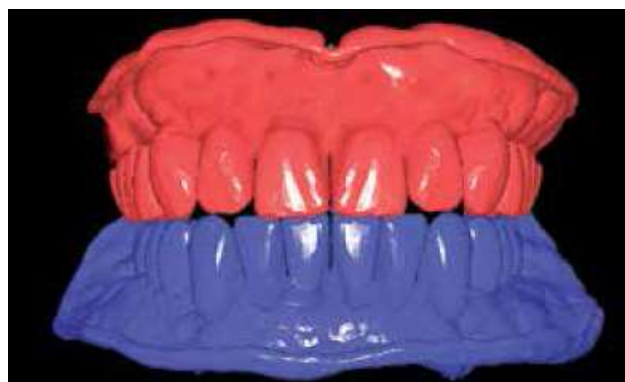


Fig 8: Digital preview of complete dentures



Fig 5: Maxillary and mandibular 2-piece impression trays used for definitive impressions and jaw relation records



Fig 9: Conventionally fabricated complete dentures at the time of placement

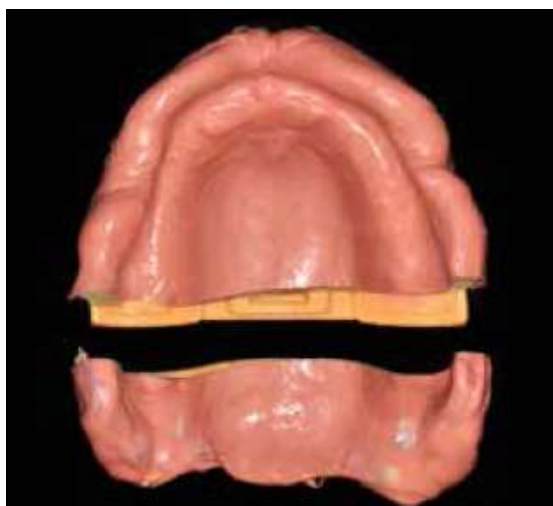


Fig 6: Posterior portion of the tray separated with the use of a blade

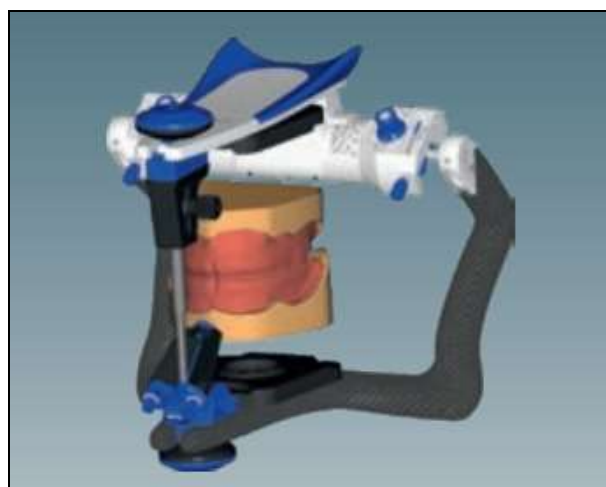


Fig 10: Casts and occlusal rims on the articulator is scanned by Ceramill Map400 scanner



Fig 11: Wax bases fabricated with Ceramill Motion 2

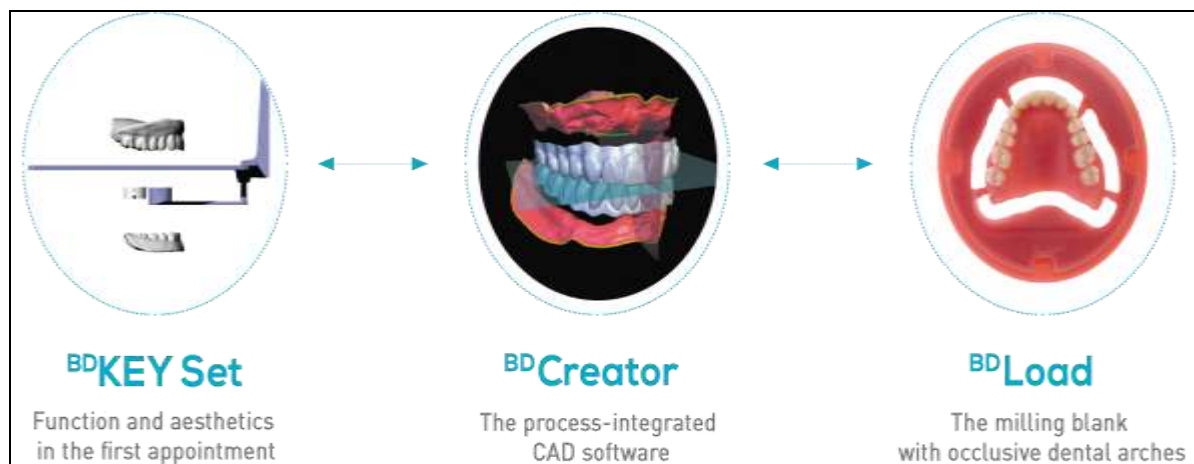


Fig 12: Baltic Denture system protocol



Fig 13: Centric tray



Fig 15: Initial impression, preliminary record of the patient's maxillomandibular relation and vertical dimension of occlusion



Fig 14: UTS CAD



Fig 16: Scanning, data transfer and customized tray design with integrated bite registration



Fig 17: Gnathometer CAD



Fig 18: Functional impression-taking and registration



Fig 19: Time-saving customized tray design and bite registration



Fig 20: The CAD/CAM-fabricated wax try-in made of VITA VIONIC WAX white in the patient's mouth.



Fig 21: The final polished denture after polymerization

4. Conclusions (Times New Roman, 12, Bold)

This article reviewed the currently available techniques being used to fabricate CAD/ CAM complete dentures. Each system has its own advantages and disadvantages, the common advantages being the reduced session protocols, reduced residual monomer, reduced polymerization shrinkage, etc. The different CAD/ CAM systems vary in the number of patient visits and method of recording occlusal vertical dimension, midline and maxillomandibular jaw relation. These systems also differ in the try in options provided by each of them.

The choice of a system should depend on the dentist's prosthodontic expertise, requirements regarding denture individualization and output rate. The initial scientific evidence braces the dominance of CAD/ CAM complete dentures, although more evidence concerning the material specific properties is necessary.

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