Computer engineering complete dentures workflow: Systematic technique's review

Abstract

The progress in the use of computer-aided design/computer aided manufacturing (CAD/CAM) to produce removable prosthodontic dentures in dental clinics has been exponential. The systems of commercially existing CAD/CAM denture techniques grow every year with increasing benefits to dentists and patients. This article assessed and evaluated the different clinical production protocols of presently accessible CAD/CAM denture systems that offer decision support for dental practitioners. Data for the current object were collected by surveys from different companies manufacturing the Computer Engineering Complete Denture (CECDs). All related subjects published at the last 10 years were collected and included in this review. Techniques were arranged in alphabetical order, as follows. AvaDent Digital Dentures (Global Dental Science), Baltic Denture Creator System (Merz Dental GmbH), and Ceramill Full Denture System (Amann Girrbach AG) can manufacture denture fabrication in three visits, including a try-in step. DENTCA Digital Dentures (Whole You Nexteeth, Inc) can also perform this in three visits. The Wieland Digital Denture (Ivoclar Vivadent, Inc) can manufacture in four dental appointments. Recently developed VITA VIONIC Digital System (VITA Zahnfabrik, Bad Säckingen, Germany) can perform two-step CECD manufacturing. Most of the techniques include subtractive manufacturing for the fabrication of their dentures and only closed systems. However, Baltic Denture System and VITA VIONIC material system are an open system that allow users to choose among different treatment protocols. It can be combined with several open scanners, CAD software options, and milling machines. The six available CECD fabrication systems offer many advantages. The decision on which technique to use may be contingent on the dentist's prosthodontic expertise, patient output amount, and requirements concerning denture individualization.

Keywords: Digital denture, Milling, CAD-CAM, Complete engineering denture

Introduction

In computer-aided design/computer-assisted manufacture (CAD/CAM), a 3D object is designed using computer software and fabricated via a fully automated process [1]. CAD/CAM has been used in dentistry since the early 1980s, especially for fixed prosthodontic restorations, such as crowns or bridges and implant abutments and maxillofacial prostheses [1,2].

Patient dissatisfaction, insufficient retention, and inadequate aesthetics were the most common difficulties associated with CECDs. The addition of a trial placement option for CECDs could result in an improved clinical outcome, thereby minimizing the incidence of other complications related to occlusal vertical dimension, centric relationship, tooth setup, and aesthetics, thereby enhancing patient satisfaction and decreasing the number of remakes. The difficulty in reading the digital preview for an objective assessment before fabrication is a unique complication for CECDs [2,3].

CECD construction offers significant advantages over the conventional processing system described by Kattadiyil 2017, such as minimizing the appointments visits, fitting improvement, and/or retention [4,5,6] and automatic filling [2]. Kattadiyil et al. reported two CECD manufacturers that used reduced appointment protocols to fabricate prostheses and considered these protocols as significantly advantageous [2,3].

For removable dentures, CAD/CAM fabrication is a novelty [1,7,8,9]. The denture base is milled from preformed acrylic resin blocks [6] that were previously polymerized under great heat and pressure. The result if a highly condensed resin that is assumed to release less monomer [10] and to have fewer microporosities. Porosities are among the factors considered for the microbial colonization of the denture base [11], which is often high, particularly among older or dependent patients [12].

The available CAD/CAM denture fabrication systems provide many advantages. The reduced session protocols appeal to dentists and patients and make complete denture prosthodontics attractive even toyoung dentists. The choice of which system to use should depend on the dentist's prosthodontic expertise, requirements for denture individualization, and throughput rate. Although the initial scientific evidence supports the clinical superiority of CAD/CAM-fabricated complete dentures, evidence regarding material-specific properties is still scarce [13-16].

This review aims to compare the clinical and laboratory protocols of the currently available CAD/CAM denture systems' workflow for the fabrication of complete dentures. The results will give an overview of the different clinical denture adaptation protocols and provide decision support for dental practitioners.

Available CECDs Systems

Although many digital systems have been proposed for digital denture construction, the precise digital duplication of an edentulous arch in its functional and dynamic forms with an accurate jaw relation remains challenging [17,18]. Currently, six systems offered by manufacturing companies are available for the fabrication of CAD/ CAM dentures; these are arranged alphabetically [13-14] as follows:

1. AvaDent Digital Dentures (Global Dental Science),
2. Baltic Denture Creator System (Merz Dental GmbH),
3. Ceramill Full Denture System (Amann Girrbach AG),
4. DENTCA Digital Dentures (Whole You Nexteeth; DENTCA, Inc; Whole You, Inc),
5. Wieland Digital Denture (Ivoclar Vivadent, Inc),
6. VITA VIONIC Digital System (VITA Zahnfabrik, Bad Säckingen, Germany).

1. AvaDent Digital Denture

Overview

AvaDent uses subtractive manufacturing to fabricate dentures. They offer two types of dentures, as follows: milled denture base with bonded teeth; and monolithic prosthesis. These are produced by AvaDent (Global Dental Science Europe BV Inc). The fabrication needs two appointments if a try-in visit to assess phonetics, function, and esthetics is not included. The high-translucency enamel and dentin core give the XCL-2 great natural esthetics. The other type of prosthesis offers a milled denture base with bonded denture teeth. AvaDent system can provide the clinician with immediate complete dentures, single-arch dentures, record bases, radiographic guides, conversion dentures, verification jigs, and definitive hybrid fixed implant prostheses [13,14].

Manufacturing appointments

AvaDent dentures can be completed in two appointments. If the clinician feels more comfortable ordering a try-in denture to assess phonetics, function, and esthetics, the digital complete dentures can be completed in three appointments. This technique involves the use of Anatomic Measuring Device (AMD), which is utilized for jaw relation records [3,10,13,19-21]. Figure 1 shows case manufacturing with AvaDent trays and AMD for CD constructions. Figure 2 shows the use of an optical scanning for partial dental arches. Figure 3 shows the use of the existing dentures of patients as trays.

First appointment includes separate definitive maxillary and mandibular impressions, which are made using supplied trays (AvaDent) after thermoplastic adaptation (A–C). Border-molded and definitive impressions are made from Condensation 2 part heavy-consistency polyvinyl siloxane (D–E). Anatomic Measuring Device (AMD) is utilized for jaw relation records (F). The AMD consists of a mandibular partial arch tray with a flat tracing table and a maxillary partial arch tray with a centrally adjustable contact point (Gothic arch tracing) and adjustable lip support flange (G–I). Correct AMD was selected and coated with specified adhesive. The AvaDent orientation ruler is attached to align the maxillary AMD to the patient's interpupillary line. The patient is asked to close his mouth until the contact point of the maxillary AMD and the tracing table of the mandibular AMD is reached (J–N). The pattern obtained resembles an arrow. Inter-occlusal registration material is injected between the maxillary and mandibular AMDs. Interocclusal registration material is injected. Composite resin is used to stabilize a transparent guide to establish midline, gingival display, and incisal edge position (O–Q). The AMDs and the definitive impressions are shipped to AvaDent. Digital preview and approval by dentist prior to milling of final dentures (R).

Second appointment/optional includes advanced try-in denture (ATI). This has a milled base with sockets into which denture teeth are secured with wax. In this appointment, denture teeth can be adjusted (if needed) by repositioning them in wax.

Third appointment. The CAD/CAM complete denture insertion is almost identical to the insertion of a conventionally fabricated complete denture (S). Pressure indicator paste or fit checker is used. Occlusal adjustment might be essential and can be performed intraorally. Severe disparity in occlusal contacts between the dentures can be adjusted following a clinical remount procedure [13,14].

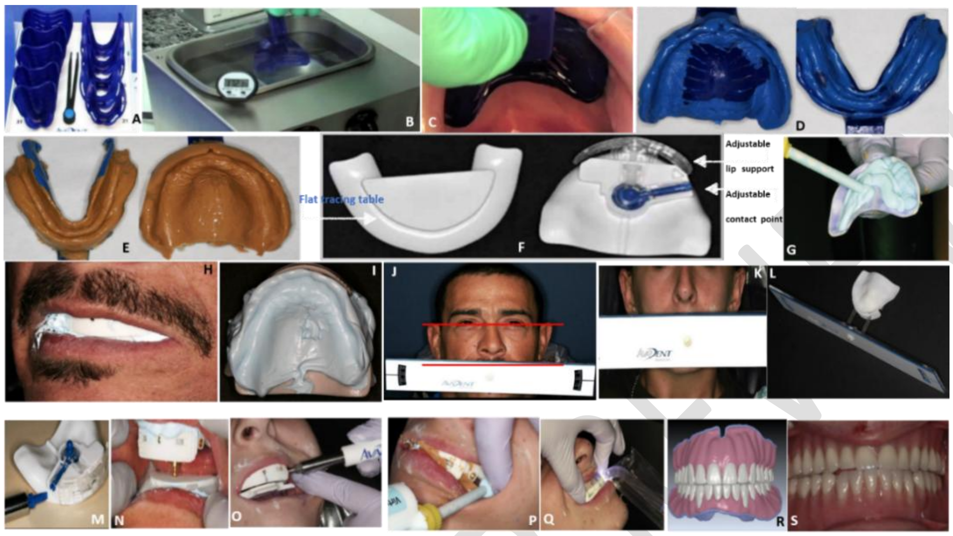

Figure 1; Thermoplastic trays in different sizes (A-C); Maxillary and Mandibular definitive Impressions with PVS (D-E). Maxillomandibular registration material placed in AMD maxillary tray (F-G). Registration of interpupillary line, the contact point is adjusted up and down using a screwdriver to establish appropriate OVD (F-L). Adjustment of the VDO using the wrench to raise or lower the pin (M-P), stabilize transparent guide (Q), Digital preview of virtual arrangement of denture during try-in (R), and final intraoral CECDs in patient mouth (S). (Kattadiyil et al., 2013; Infante and Yilmaz., 2014, Steinmass et al., 2017, Contrepois et al., 2018; Goodacre, et al., 2018; Srinivasan et al 2019).

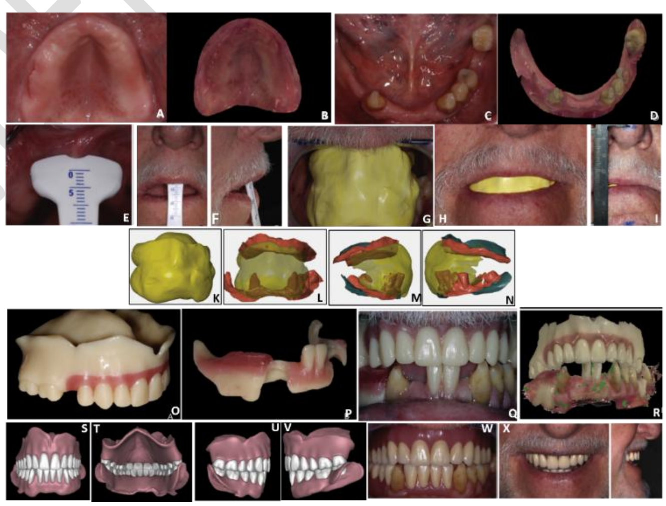

Figure 2; Optical scans of edentulous maxilla (A-B), partially edentulous mandible (C-D). Registering lip length with Papilla-meter (AvaDent; Global Dental Science Europe BV), Positioning of Papilla-meter for measuring lip length while maintaining lip in relaxed state (E), Lateral view showing positioning of Papilla-meter to maintain labial support (F). Jaw relations by a ball of polyvinyl siloxane putty placed between jaws, patient instructed to close gently (G), Lips molded gently to establish approximate lip support and fullness (H), Establishing arbitrary approximate vertical dimension of occlusion (I), Aligning optical scans with scan of putty block record, Frontal view, right lateral view, Left lateral view of aligned scans (K-M), Definitive jaw relation with record bases (N). Maxillary with tooth arrangement in wax to first premolars with milled molar (O), Mandibular with central incisors and posterior occlusal wax blocks (P), Centric relation (Q), Optical scan of WTIs in centric relation to register definitive jaw relation (R), Digital preview showing virtual tooth arrangement, Frontal view, Posterior view, Right lateral view, Left lateral view (S-V), CAD-CAM milled CDs intraoral retracted frontal view of inserted dentures (W), Frontal view of smile with dentures in place and profile view of smile with dentures in place (X). (Steinmass et al., 2017; Srinivasan et al 2019).

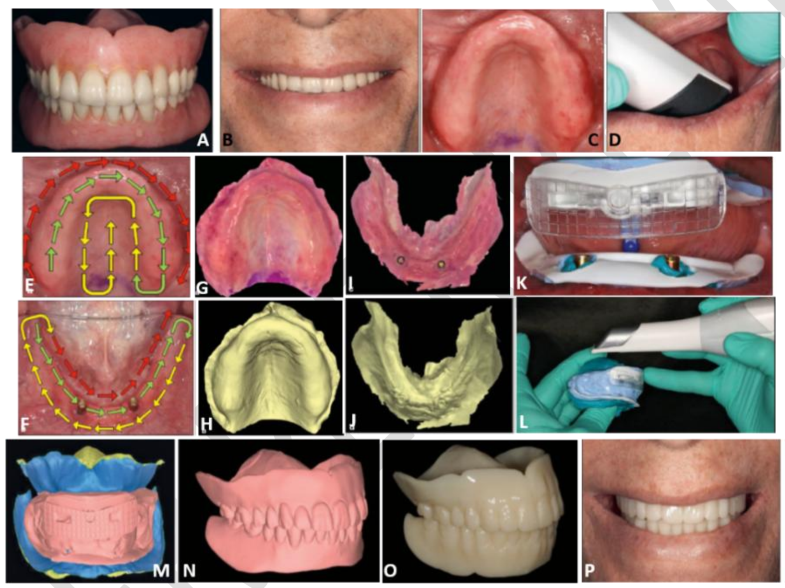

Figure 3; Patient's existing denture fabricated 15 years ago (A), Pretreatment smile (B), Occlusal view of the maxilla (C), Finger retraction of cheeks to determine vestibular depth (D), Suggested scanning pathway for maxillary arch (E), Suggested scanning pathway for mandibular arch (F), Intraoral scan of maxillary arch in color (G), Maxillary scan without color. (H), Scan of mandibular arch in color (I), Mandibular scan without color (J), Gothic arch-tracing device (K), Intraoral scan of gothic arch-tracing device (L), Digital mounting of intraoral impressions using interocclusal record (M), Intraoral scan of denture (N). CAD/CAM esthetic try-in denture (O), Intra-oral CAD/CAM–milled monolithic definitive denture (P). (Infante et al., 2014; Goodacre et al., 2018, Srinivasan et al., 2019).

2. Baltic Denture System

Overview

The designed Baltic Denture System (BDS) is for correcting bite rims or occlusal rims containing preformed occlusal arches (BD Keys Set Component, Merz Dental GmbH). It uses subtractive manufacturing for the construction of dentures. Figures 4A and B show that relining is performed until the dental arches are positioned in the anatomically accurate 3D position with two appointments [13-14,22].

Construction Steps

The presence of teeth on the different sizes trays (Figure 4C) permits evaluation of the overall aesthetics, lip support, tooth alignment, and interocclusal space. The BD-KEY trays identically replicate the size and shape of the denture teeth in the milling blocks; thus, these trays serve as try-in dentures to confirm the patient's approval of the future dentures. BDS protocol contains one adjustment clinic and the denture insertion appointment. Baltic Denture Creator System is produced by Merz Dental GmbH.

Firstly, the vertical occlusal dimension (VOD) is measured. Then, a functional impression is reserved. The trays are adjusted intraorally. Afterward, by supporting the BD maxillary Key (a bite rim resembling the master maxillary dental arch) with silicone impression material or thermoplastic impression compound, the occlusal plane, incisor length, and lip support are determined. When the maxillary MXDA has been adjusted to the perfect location, the BD mandibular Key (a bite rim approximating the ultimate MUDA) is joined with the BD maxillary Key by click device and again reinforced with silicone impression material to reach the formerly determined VD and the CR. The BD Keys resemble the final dental arches. The adjusted keys also serve as try-in dentures, so that the final dentures can be placed at the coming appointment (Figure 4D).

Next, following the milling of the complete denture, the placement is similar to that of any conventional complete denture. Occlusal adjustment can be performed intraorally or by using a clinical remount procedure. Alternatively, the usual impression trays are utilized, and then, the remaining steps are digitized (Figures 4A2–G2). [13,14,22].

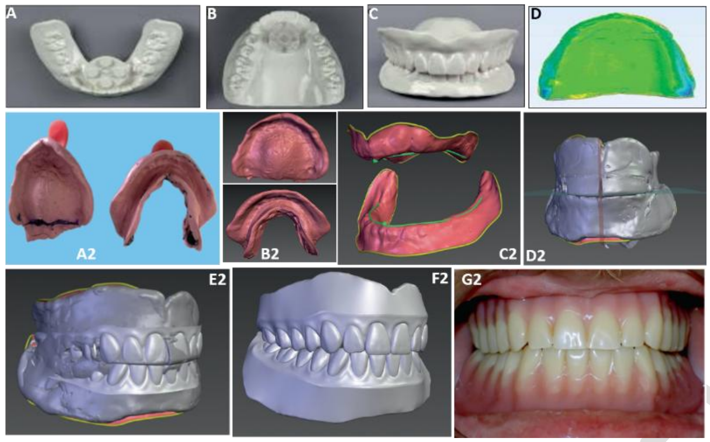

Figure 4; Mandibular BD Key (A), Maxillary BD Key (B), and both keys click-fixed together (C), High congruence between milled CAD/CAM denture base and master cast. Green = maximal concordance; turquoise and yellow = less concordance. Maxillary and mandibular definitive impressions (Figure 4A2), Stereolithography (STL) files after importing into software, Maxillary and Mandibular (Figure 4B2), Denture boundary line created by setting path points to form line (Figure 4C2), Occlusal rim, occlusal plane, and midline incorporated into image in software (Figure 4D2), Alignment of dental arches according to occlusal rims (Figure 4E2), Digital preview of virtual arrangement (Figure 4F2), Intraoral frontal view of definitive maxillary and mandibular CDs (Figure 4G2) (Yilmaz et al., 2016).

3. Ceramill Full Denture System

Overview

The Ceramill denture system is similar to the AvaDent digital system. It is two-visit system and manufactured by Amann Girrbach (AG), Germany. It uses subtractive manufacturing for the construction of dentures [13, 23-24].

Manufacturing visits

First visit. The existing complete dentures are used as custom trays to record the definitive impression of the edentulous arches via the closed mouth technique using a light-body VPS material. The patient is instructed to perform functional movements of the mouth to record a dynamic impression of the buccal and lingual vestibule (Figure 5A). Then, the maxillary and mandibular dentures are removed from the patient's mouth when the impression material is completely set. The dentures are digitized with an intraoral scanner. In this step, all the denture surfaces, including the impression, intaglio, and cameo surfaces, are scanned. The scanning of the maxillary impression starts at the distobuccal area on one side and moves toward the anterior area, the soft palatal areas, and finally, the distobuccal area on the other side (Figure 5B). For mandibular impression, scanning involves moving the scanner head in a slow zigzag manner, starting at the distal area on one side and following the ridge crest to the opposite side (Figure 5B). The dentures are placed back in the patient's mouth, and their stability is ensured (Figure 5C). Next, the CR is recorded with an intraoral scanner. At the end of this appointment, the alignment function of the scanning software is used to automatically align the two digitized denture images to CR using the bite scan area (Figure 5D) [13,14, 22-24].

At the laboratory, the scanned maxillary and mandibular denture image format is saved and transferred to a 3D image control computer software program. The entire scan image is segmented into three parts, namely, the maxillary impression, the mandibular impression, and the dentition parts. These parts are saved separately in the software format. Afterward, the digital impressions of the intaglio surface of the denture are inverted to create a digital model of the maxillary and mandibular arches by using the software. In this step, the digital models of the edentulous arches are digitally constructed in the correct inter-arch jaw relationship and are ready to be used for designing the denture (Figures 5D–E). The digital maxillary and mandibular edentulous arches, as well as the dentition part, are transferred into a dental design software to design the denture base and arrange the artificial teeth for the new complete denture (Figure 3F). The design includes arrangements of the teeth on the existing arches in CR. Finally, the setting up of teeth is performed.

Second visit. The denture is inserted into patient's mouth after the adjustment of occlusion (Figure 5G). Another case is presented in Figures 52A–2S [23-24].

Figure 5; Using existing denture as close-fitting tray to take functional impression of edentulous arche (A), Optical scanning pathway of impression surfaces of dentures (B), Whole digitized denture image aligned to the centric relation position by using a digital bite scan (C), Formation of maxillary and mandibular digital working models for denture design, Segmentation of whole scan image into the maxillary and mandibular impression part, and dentition part (D-E), Conversion of the negative form of the digitized impression image into positive form using image reversal technique to generate digital working models (D-E), Design of definitive denture on the digital working mode, Import of the dentition part image of the existing denture as a reference in the inter-arch space (F), Design of definitive denture (G). Mounted master casts, master casts and record bases fixed on articulator (Figure 5A2), Reference points marked on master casts in CAD software [Midline maxillary tuberosity (Figure 5B2), Occlusal plane (Figure 5C2), Final setup lines for maxilla (Figure 5D2), and for mandible (Figure 5E2), Artificial teeth arrangement (Figure 5F2), in Maxilla (Figure 5G2), and arrangement in scanned record rim (Figure 5H2), Articulator mounting (Figure 5I2), Denture design (Figure 5K2), Basal adaptation of artificial teeth (Figure 5L2), Milled maxillary (Figure 5M2), and mandibular wax denture base (Figure 5N2), Milled artificial teeth (Figure 5O2), Maxillary upper surface with milled artificial teeth inserted (Figure 5P2), Milled wax dentures in articulator, notice the contact of incisal pin (Figure 5Q2), Milled wax denture try-in (Figure 5R2), and Definitive complete denture inside patient mouth (Figure 5S2) (lee et al., 2019; Mai et al., 2020).

4. DENTCA Digital Denture/Whole You Nexteeth

Overview

DENTCA's concept is similar to that of AvaDent, except that DENTCA uses a proprietary impression tray with a detachable and re-connectable two-piece maxillary tray and a three-piece mandibular tray with a built-in intraoral tracer. The tray can register a final impression and an interocclusal record simultaneously. The DENTCA system uses one set of impression trays, whereas the AvaDent system requires one set of trays and one AMD [13-14]. The DENTCA system was introduced to the market by Whole You, Inc and DENTCA system, Inc, Mitsui Chemicals Group [25].

Manufacturing procedures

Provided mandibular and maxillary two-piece trays are selected. These are used to make the definitive impressions and record the maxilla-mandibular relationship. A #15 surgical blade is used to slice through the impression material on both the maxillary and mandibular impressions. The anterior sections of the trays are repositioned in the mouth for jaw relation records [14,25].

During the first patient visit, anatomical alginate impressions are generated using conventional impression or centric trays (Figures 5a and b). In addition, the vertical dimension and provisional jaw relation are registered using the so-called centric tray, and the occlusal plane is determined provisionally using a special instrument, namely, the UTS CAD transfer arch (Figure 5c). In the laboratory, milled maxillary and mandibular individuals' trays are prepared (Figures 5d and e). The UTS CAD device is used to create primary digital model positioned on a virtual articulator (Figure 5f) [14].

During the second visit, optionally, functional maxillary and mandibular silicone impressions are taken (Figures 5f and g) with milled individual impression trays that already contain the information about the vertical jaw relation and the occlusal plane. If necessary, both impressions can be adjusted by observing the compensation values registered by the UTS CAD transfer arch. The gothic arch is then registered using the functional impressions. A click-in set called gnathometer CAD, which is a cutback, is integrated to leave sufficient space for the intra-oral center-point recording system (Figures 5h and i). In the laboratory, the gnathometer CAD can be easily clipped to tray impressions and does not require bonding or retention (Figures 5K and l). Gysi Gothic arch paths meet at an equilibrium area used as a reference during the inter-arch relationship recording step. Then, Gysi Gothic arch is registered with Gnathometer® (Figures 5m and n). The embedded functional impressions are scanned, and a drawing of the limit of the future denture base is obtained. Numerical models are placed on the virtual articulator, and reference points are identified. Teeth setting is proposed by the 3-shape software with posterior teeth positioned in an ideally bilateral balanced occlusion concept. Then, virtual wax finishing step was digitally performed. Finally, the manufactured maxillary and mandibular templates are presented on a white PMMA disc (Figure 5).

Third appointment. The CAD/CAM complete denture insertion is almost identical to that of a conventionally fabricated CD. Pressure indicator paste or Fit Checker is used. Occlusal adjustment might be essential and could be performed intraorally. Severe disparity in occlusal contacts between the dentures can be adjusted following a clinical remount procedure. [13,14,25].

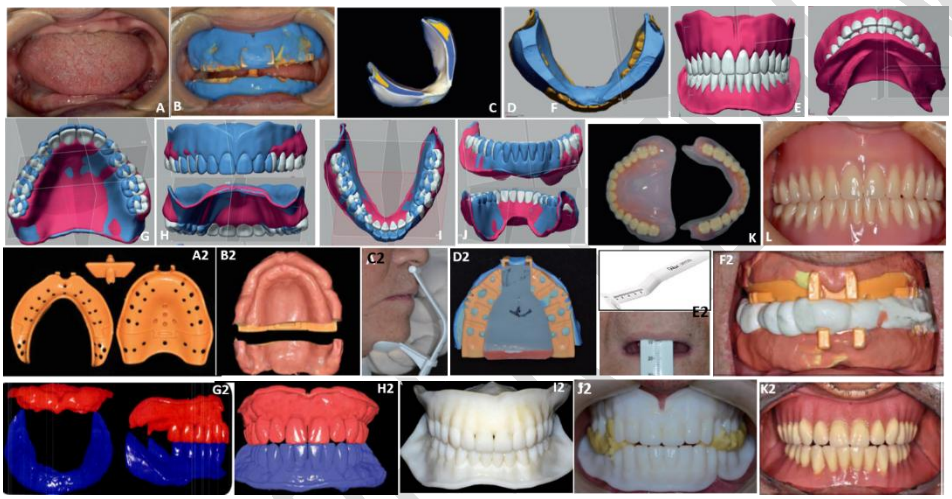

Figure 6; Maxillary and mandibular arches with severe ridge resorption (A), Definitive impressions and maxillomandibular jaw relationship Registration (B), Impression of mandibular denture cameo surface (piezographic space) made by 3-step procedure in which patient was asked to repeat distinctly pronounced sounds (C), Superimposed piezographic space and original denture design with tooth positions arranged conventionally (D), Comparison between original (left) and modified (right) virtual complete denture images (E and F), Superimposed original and modified virtual complete denture images, Blue area, original design (G-J), Maxillary and mandibular complete dentures milled from acrylic resin block and commercially available denture teeth bonded with resin adhesive (K), Completed dentures inside patient mouth (K) (Ohkubo et al., 2017). Maxillary and mandibular 2-piece impression trays (A2), Posterior part is separated with the use of a blade (B2), Dentca jaw gauge (C2), Dentca Lip ruler (E2), Interocclusal registration material is injected (F2), optical scanning of maxillary and mandibular arch in CR and set-up of anterior teeth (G2), Virtual try-in denture, try-in denture (I2), Jaw relation recording on try-in denture (J2), and Definitive complete denture inside patient mouth (K2) (Steinmass et al., 2017; Contrepois et al., 2018; Srinivasan et al 2019).

5. Weiland Digital Denture

Overview

The protocol of Wieland Digital Dentures involves four appointments, which are necessary for the fabrication of CDs. Alternatively, three visits are required if the try-in session is omitted. The system uses subtractive manufacturing to fabricate CDs. The clinical records can be gained by replicating present CDs and transferring them to the dental laboratory by using wax rims that are digitally designed and milled or by means of numerically designed and customized impression trays with combined bite plates [13,14,26].

Fabrication procedures

In the clinic, maxillary and mandibular preliminary impressions are made with PVS impression material and prefabricated trays. The provided centric record device is used to register the preliminary CR and vertical relationship. The manufacturer uses this information to customize impression trays with integrated bite plates. A device similar to a facebow (UTS CAD, Ivoclar Vivadent, Inc) is connected to the handle of the centric tray to help the clinician measure the camper and interpupillary lines.

The position of the occlusal plane can be read from the measurements obtained from the camper and interpupillary line scales. The preliminary impressions, centric tray, and the camper and interpupillary line measurements are sent to the laboratory technician.

In the laboratory, the preliminary impressions and the interocclusal record are scanned. Camper line and interpupillary line values are entered into the design software, which then produces virtual models of the edentulous jaws and determines the patient-specific occlusal plane. Customized impression trays with integrated occlusion plates are designed with a uniform offset to allow for the application of impression material and with a recess to allow the stabilization of the Gnathometer CAD (Ivoclar Vivadent, Inc), which is a device that allows the tracing of the gothic arch and records CR.

Intraorally, the customized impression trays are border molded, and then, a definitive impression is made using a PVS material. The UTS CAD is used again to verify the occlusal plane. The Gnathometer

CAD is attached to the customized trays. The patient's midline, smile line, and canine-to-canine line are established, and the VDO and CR are determined with traditional methods.

In the laboratory, the records and the functional impressions are scanned, and the occlusal plane is determined. At this stage, the denture teeth are chosen from the software library of denture teeth, and the design program suggests a virtual tooth setup. The tooth setup can be modified according to the demands of the clinician and patient or finalized by adding the gingival portion of the dentures if no changes are requested. If the clinician feels more comfortable ordering a try-in denture to assess phonetics, function, and aesthetics and to enable corrections to the try-in denture (if necessary), then the dental technician can mill a monolithic PMMA try-in denture. A prepolymerized disk is used to mill the gingival portion of the denture bases. The bases include milled recesses, in which the denture teeth will be bonded with the use of a positioning jig.

Clinically, after the milling of the CD, the placement is performed. Placement is similar to that of any conventional CD. Occlusal adjustment can be performed intraorally or by using a clinical remount procedure [13-14,26].

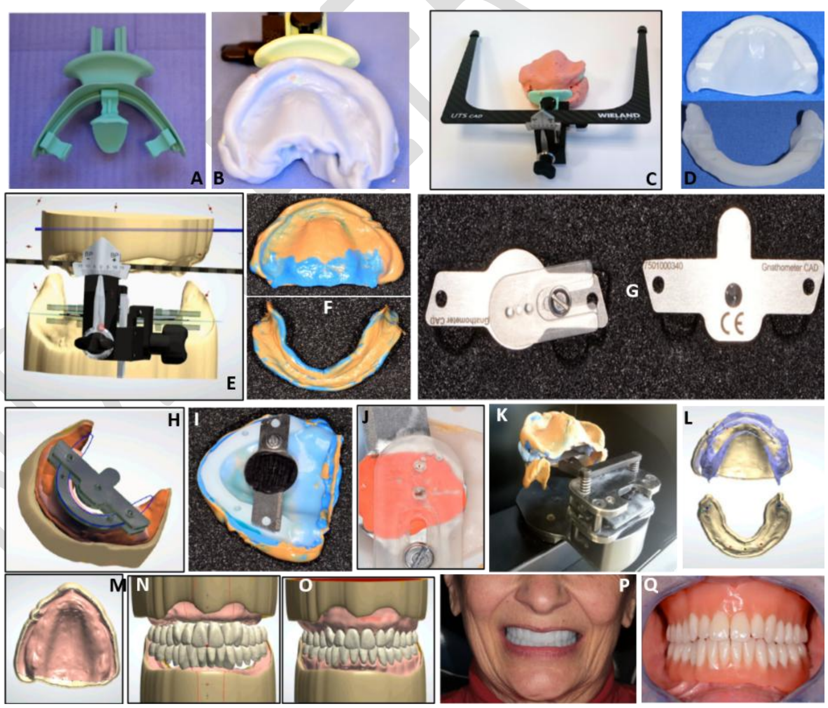

Figure 7; Centric Tray®, Recording of preliminary inter-arch report with the Centric Tray® and high viscosity elastomer, UTS CAD® (A-B), UTS CAD® device connected to the Centric Tray® for recording deviations from reference planes (C), Maxillary and mandibular individual milled tray (D), Values of UTS CAD® device are used to create primary digital model positioned on virtual articulator (E), Maxillary and Mandibular conventional functional impression with manufactured tray (F), Gnathometer® (G), cutback is integrated to leave sufficient space for intra-oral center-point recording system (Gnathometer®) and to avoid any interference between antagonist occlusal rims (H), Gnathometer® clipped to tray impressions and without bonding or retention (I), Gysi Gothic arch paths meet at an equilibrium area used as a reference during inter-arch relationship recording step (J), Embedded functional impressions are scanned (K), Numerical models are placed on virtual articulator and identified reference points (L), Drawing of limit of future denture base (M), A teeth setting is proposed by 3shape software with posterior teeth positioned in an ideally bilateral balanced occlusion concept (N), Virtual waxes finishing step (O), Occlusion rims are validated and patients use their manufactured template for functional validation (mastication and phonation) for while at home (P), Dentures are tried, and primary equilibration is performed (Q) (Baba, et al., 2016; Bonnet et al., 2017; Steinmass et al., 2017)

6. VITA VIONIC VIGO (VITA Zahnfabrik)

The VITA VIONIC VIGO 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 supports whatever adjustment protocol to which the user is accustomed. Therefore, a five-step conventional denture fabrication protocol can be applied. Alternatively, a reduced-session protocol with only three sessions (anatomical impression, functional impression plus determination of vertical and maxillomandibular jaw relation, and denture placement) can also be applied. The impressions, casts, or registrations are generated conventionally and digitalized, thereby entering the CAD/CAM manufacturing pathway. If a try-in session is desired, the try-in dentures can be milled from wax discs provided by VITA system [13,27-28]. VITA VIONIC VIGO is the first denture tooth that has been perfected for the digital workflow. The tooth has already been preconditioned and shortened basally. After the additive or subtractive fabrication of the denture bases, it is simply removed from the blister pack and fixed into the designed alveoli using the special VITA VIONIC BOND adhesive. The bond is extremely thin and clean. Moreover, it saves time because of the precise and stable fit. Any person can fit it. Sometimes, just a small detail is missing to make this technology work for everyday laboratory use. Figure 7 shows the procedures for the construction of CECDs [27-28].

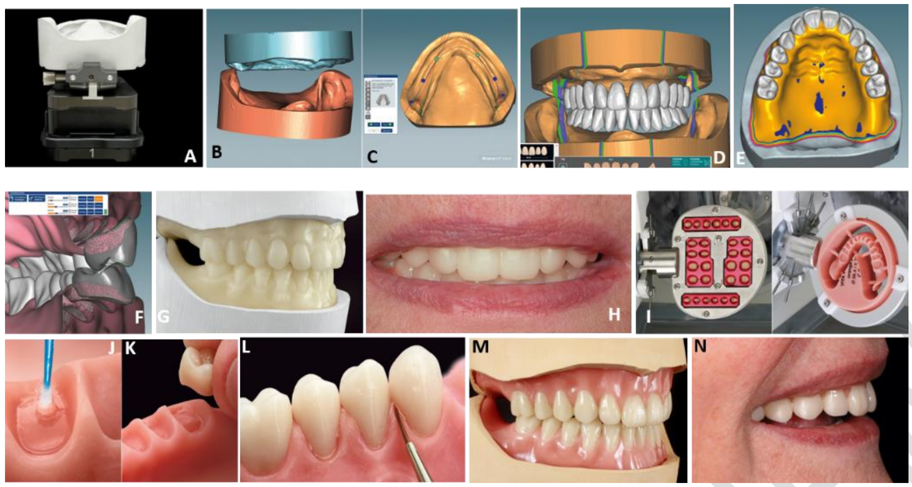

Figure 8; Mandible model before digitalization with laboratory scanner (A), Digitalized model in clinically determined vertical dimension (B), Model analysis by Software (C), Virtual setup was performed by pushing button after tooth selection (D), Design of denture base (E), Cross-sectional view of ideal dentition in molar area (F), CAD/CAM-fabricated wax try-in was made Midline(G), occlusion level and phonetics were checked using a wax try-in (H), Modification of teeth, teeth in the VITA VIONIC FRAME were modified circularly and basally (I), Denture base was fabricated from PMMA blank VITA VIONIC BASE (J), Milled PMMA alveoli were moistened with VITA VIONIC BOND, dislodged basal teeth bonded with adhesive, accurately fitting in denture (K), Closing of interdental spaces with veneering composite VITA VM LC flow (L), After polymerization in the pressure pot and final polishing is done (M), Denture in the patient mouth (N). Patient was enthusiastic about the positional stability and natural effect of the VITAPAN EXCELL denture teeth [Körholz K-H, 27-28].

Discussion

Currently, the six available CECD fabrication systems offer a number of advantages, and the decision on which technique to use may be contingent on the dentist's prosthodontic expertise, patient output amount, and requirements concerning denture individualization. Nowadays, the progress in the use of CAD/CAM to produce removable partial or complete dentures has been exponential in dental centers or clinic market, and the number of commercially existing CAD/CAM denture systems increases yearly [14,29]. Figure 9 gives a summery of the steps of the 6 avaliable systems.

Mai and Lee., 2020 described a well-organized digital workflow for recording functional edentulous arch images with precise inter-arch relationship (centric relation). In addition, exact tooth setup in CAD programs is established by using intraoral scanner for an existing denture and digital denture scanning. The new denture can be planned competently and predictably [24]. Goodacre et al., 2018 described a technique by using intraoral scanning to capture CD impressions. This scanner can capture an accurate mucostatic impression and results in a good mucosal adaptation and stability of the CAE-CD milled prostheses. This system can record the CR and is efficient in the clinical steps. It minimizes the need to transport conventional records to the dental technicians [20].

Steinmassl et al., 2017 stated that the existing CAD/CAM denture fabrication systems offer a variation of advantages, and the choice on which technique to use should rely on the prosthodontic and dental technicians' expertise, patient amount rate, and necessities concerning denture individualization [13].

Srinivasan et al., 2019 published a technical statement describing the workflows for manufacturing CECDs by using a novel, custom-modified tray to successfully fabricate CAD-CAM milled CDs and resin interim removable partial denture [21]. Also, AlHelal et al., 2017 and Batisse et al., 2021 tried to overcome the difficulties regarding digital performances that can result in additional appointments and costly remakes of CEM-CDs. They presented a good technique that resulted in good aesthetics, fitting, and retention [4, 30].

Pacquet et al., 2021 said that composite resin and lithium disilicate glass-ceramic material reveal acceptable dimensional accuracy, and milling glass-ceramic before crystallization significantly enhances dimensional accuracy [31].

Every system has a drawback. For example, in AvaDent, the adjustment steps are made in one session, which may be stressful for CAD/ CAM-denture learners. However, the system was graded as "easier to perform" than the other systems. Failure can be adjusted during the try-in step [13-14]. In addition, this system is the most used for fabricating different type of prostheses and can accommodate many steps and instruments or materials from other types of procedures (Figures 1–3). BDS cannot fabricate a single-arch denture; dysgnathia also represents a limitation; and training is needed before it can be applied to patients [13-14,22]. Some digital systems do not offer a try-in step, which can cause complications during delivery. DENTCA DD can be used in the presence of severe bone ridge resorption.

The system used does not provide all schemes of occlusion and is only available with a lingualized occlusion option. No long-term results have been published. Current commercial protocols should be validated through sound clinical and laboratory research and improved if necessary to overcome the disadvantages listed. Clinician feedback is essential if the manufacturers wish to improve the current treatment protocols.

Six systems exist, and others are being developed. Clinical and laboratory investigations have been conducted, but not on all of the available systems. Nevertheless, current research indicates that this talented digital workflow benefits both the dental technician and the dentists or clinicians.

Concluding Remarks

Based on the findings of this systematic review of CECDs, the following conclusions are drawn:

- Techniques and machines are continually changing and improving in mechanical and surface properties to overcome and/or minimize the patient's overall dissatisfaction in terms of aesthetic, bulkiness, and inadequate retention.
- In all techniques, post insertion adjustments are performed in the conventional way. The systems can accept the using of old dentures if they are utilized in the try-in for the new CECD fabrication. Most of the systems accept external staining for denture teeth.
- Try-in for the virtual dentures is highly recommended in all techniques, because it minimizes most of the negative outcomes in various aspects, such as aesthetics, retention, size of selected teeth, vertical dimension of occlusions, centric relation verification, and overall profile of the patient face. In most of the techniques, the white acrylic resin is used.
- Issues in the interpretation of the digital preview was recognized as a unique difficulty related to the fabrication of CECDs.
- Each technique has its own advantages, disadvantages, and limitations, but all techniques preserve a digital record, which is a great advantage for older adults with limited access to dental care.

- Other advantages of CECD fabrication techniques over conventional ones are as follows: elimination of the use of stone, flasking, and processing techniques; and absence of monomer usage and its effects.

  - **COMPETING INTERESTS DISCLAIMER:**
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  - Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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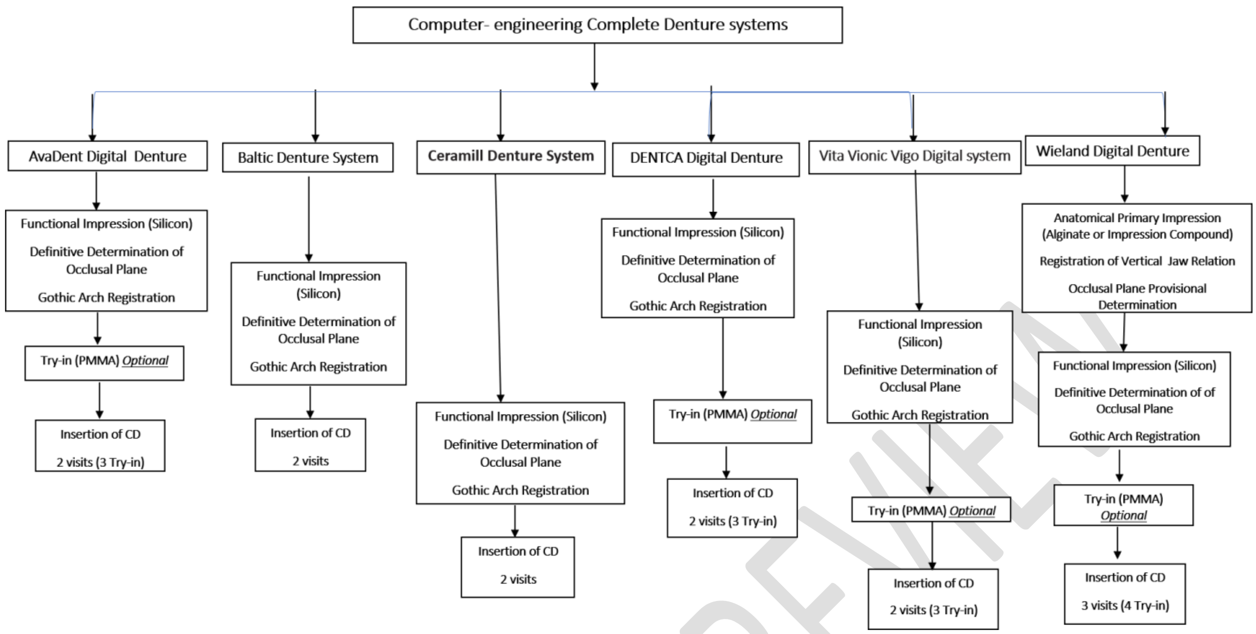
Figure 9 summery of the steps of the different CECDs construction systems


Computer- engineering Complete Denture systems
AvaDent Digital Denture
Functional Impression (Silicon)
Definitive Determination of Occlusal Plane
Gothic Arch Registration
Try-in (PMMA) Optional
Insertion of CD
2 visits (3 Try-in)
Baltic Denture System
Functional Impression (Silicon)
Definitive Determination of Occlusal Plane
Gothic Arch Registration
Insertion of CD
2 visits
Ceramill Denture System
Functional Impression (Silicon)
Definitive Determination of Occlusal Plane
Gothic Arch Registration
Insertion of CD
2 visits
DENTCA Digital Denture
Functional Impression (Silicon)
Definitive Determination of Occlusal Plane
Gothic Arch Registration
Try-in (PMMA) Optional
Insertion of CD
2 visits (3 Try-in)
Vita Vionic Vigo Digital system
Functional Impression (Silicon)
Definitive Determination of Occlusal Plane
Gothic Arch Registration
Try-in (PMMA) Optional
Insertion of CD
2 visits (3 Try-in)
Wieland Digital Denture
Anatomical Primary Impression (Alginate or Impression Compound)
Registration of Vertical Jaw Relation
Occlusal Plane Provisional Determination
Functional Impression (Silicon)
Definitive Determination of of Occlusal Plane
Gothic Arch Registration
Try-in (PMMA) Optional
Insertion of CD
3 visits (4 Try-in)