CAD-CAM COMPLETE DENTURES - A REVIEW OF LITERATURE

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***Abstract*- This research delves into the evolving application of Computer-Aided Design and Computer-Aided Manufacturing (CAD-CAM) in crafting complete dentures, signifying a paradigm shift in prosthodontics with improved precision, efficiency, and patient outcomes. The study explores CAD/CAM dentures' properties in comparison to traditional counterparts and diverse fabrication systems within digital dentistry. Its objective is to clarify the integration of CAD/CAM throughout the entire denture-making process, from digital impressions to creating highly personalized complete dentures. The abstract highlights the benefits of digital workflows, emphasizing precision, reproducibility, and patient satisfaction. Furthermore, it touches upon the variety of materials and manufacturing methods used in digital denture systems, aiming to provide a comprehensive overview of current practices and summarize related literature on CAD/CAM complete dentures.**

INTRODUCTION:

The edentulous arches are influenced by a combination of biological and patient-specific factors, making it a complex and multifactorial phenomenon[1,2]. For this, complete dentures have been used conventionally as a means of rehabilitation[3-5]. However, the conventional CDs take more time for the fabrication process, more clinical chairside time and impression making causes patient discomfort and hindrance. The complexity of manipulation leads to overextended borders which cause ulceration of the tissue. The time-consuming procedures of waxing, investing and wax elimination, the greater dimensional changes of PMMA resins and less fracture resistance results in poor adaptation of the intaglio surface. Residual monomer causes patient's soft tissue irritation and allergic reactions to some of the patients. Surface roughness and porosity from processing induce microbial accumulation to the dentures, all of that can compromise oral hygiene[6-10]. To overcome the limitations of conventional CDs, paved the way for the introduction of the digital denture workflow for fabrication in the dental field. Digital dentures can be fabricated within hours, overall patient satisfaction, less discomfort and better adaptation, less space for data storage, all make digital dentures popular in dental practices. Intra Oral Scanning provides better and improved detection and visualization of the morphology of the edentulous arches, especially in the palate shape[11-15]. To understand, digital dentures comprise both computer-aided technology and machining (CAD/CAM) and computer-engineered complete dentures (CECD). Computer-aided technology or digital technology is a wide term which indirectly refers to the skills to aid in the design, analysis and manufacture of products with the use of computers.

CAD/CAM technology has multiple applications in dental practices and it has been over two decades with improved outcomes & the scope for that in the future is increasing. Therefore, this study aimed to summarize and review the published papers related to the properties and various digital denture systems of CAD/CAM complete dentures.

COMPONENTS OF CAD/CAM:

The three key components make up CAD/CAM systems are :

(1) A data acquisition unit gathers information from the preparation area, adjacent structures and opposing elements, converting them into virtual impressions using intraoral scanners or traditional impressions with a stone model[43].

(2) The CAD segment employs the acquired data to generate a virtual model of the restoration or prosthesis[43].

(3) The CAM part translates the virtual model into precise instructions for the manufacturing process, whether it involves milling or 3D printing the final restoration or prosthesis[43]

The CAD/CAM is classified as additive manufacturing (rapid prototyping) and subtractive manufacturing (computerized numerical control [CNC] machining) and both use images from a digital file[16]. Additive manufacturing or 3D printing creates an object by laying down successive layers of a chosen material while Subtractive manufacturing creates an object by machining (cutting / milling) which physically removes material to achieve the desired geometry[13,17,18].

PROPERTIES:

The CAD/CAM complete dentures and conventional dentures are compared in terms of their properties. The included studies showed significant variations but are summarized as follows.

1) TRUENESS AND ACCURACY OF FIT

The CAD/CAM milled complete denture shows overall improved fit in the intaglio surface of the palatal vault, alveolar crest, posterior seal area and the tuberosity region, thus preventing traumatic ulcers and provides better retention. However, the printed denture shows reduced reproducibility and is time-consuming[7,19-23]. Among the digital denture systems, AvaDent shows the highest tissue adaptation[22].

The Yoon et al . study showed that mandibular bases from milling produce better adaptation than printed bases. He also stated that tissue adaptation was uniform in milled bases. Tissue compression was noted in the 3D-printed base in the posterior crest region which requires some chairside time for adjustment[20,24].

The Hwang et al . study showed that the printed base provides better adaptation than milled base in maxillary denture bases[20,25].

2) FLEXURAL STRENGTH

Most of the studies showed, that no significant change was noted between CAD/CAM and conventional dentures in terms of flexural strength. However, a study conducted to compare the surface properties showed a significant increase in flexural strength for CAD/CAM PMMA than conventional heat polymerized PMMA[11,20,27,28].

3) FLEXURAL MODULUS

In terms of flexural modulus, CAD/CAM PMMA resins show higher modulus leading to thinner manufacturing of the denture with increased fracture resistance leading to better retention and comfort[11,20,28,29].

4) FRACTURE TOUGHNESS and RESISTANCE

CAD/CAM dentures afford higher modulus of elasticity, thus providing increased fracture toughness. This makes the denture to manufacture thinner and at a uniform thickness. Thus, it provides a better and more natural speech for the patients[11,20,27,30].

3D-printed denture teeth resins tested for chipping and indirect tensile fracture resistance showed adequate resistance[20].

5) WETTABILITY or HYDROPHILICITY

Alammari [32], Steinmassl et al[34] and Arslan et al.[35] compared CAD/CAM PMMA with conventional PMMA and showed a lesser contact angle which is more wettability in the CAD/CAM PMMA resins[20].

Increased wettability shows increased retention of the denture[11]. Thus, in patients with salivary dysfunction, dentures made of CAD/CAM PMMA resins will provide better retention[20].

Microbial adhesion to the denture will be less in increased hydrophilic nature[31]. Hence, the colonization of Candida sp. and other microbes will decrease in percentage than conventional dentures[11,20,26].

6) SURFACE ROUGHNESS

Surface roughness plays an important role in the biofilm adhesions and also causes surface staining[34]. Monomer content and polymerization method contribute to the surface roughness[26,29,31,32]. During processing, the milled denture produces undulated ripples. The size depends on the quality of the milling tools and the process. The surface quality improves when the manufacturing of CAD/CAM dentures is done under high pressure and temperature. Decreased roughness produces increased wettability, reduced biofilm retention and stainability[11,20,26,34]

7) COLOR STABILITY and SURFACE STAINING

By the change in surface staining, the denture base material ageing and damage were detected. In spite of the hydrophobic nature of the denture base, the colorants in the drinks such as coffee have a deeper depth of penetration into the denture base. In CAD/CAM dentures, the interface between the denture base and the teeth shows stainability which is less than conventional dentures. But visual evaluation of the interface shows better resistance to discolouration[20,36].

Other than coffee, beverages such as red wine, tea and cola showed no significant change in the surface stainability suggesting that coffee has strong chromogenic agents (tannic acid) which penetrate greater depth of PMMA. However, the acidic pH of red wine could affect the denture base, causing surface roughness and further leading to surface staining. However, using prepolymerized PMMA blocks was promising in the optical properties[20,36].

8) RESIDUAL MONOMER CONTENT

Under high pressure and temperature, the CAD/CAM PMMA prepolymerized leads to forming longer polymer chains resulting in reducing residual monomer. Thus, it leads to a reduction in porosity and free volume and also indirectly reduces biofilm retention[11,20,29,30].

9) CLINICIAN AND PATIENT REPORTED OUTCOME ([a]RETENTION & AESTHETICS and [b]PATIENT SATISFACTION)

The peripheral seal, the fit of the denture base and a sufficient layer of saliva played a major role in denture retention. By air depression between the denture and the mucosa and minimal or no shrinkage during polymerization provides better retention than conventional one[37,46]. However, lack of trial placement resulted in inaccurate records and esthetic dissatisfaction for the patients. Setting up the mandibular plane is impossible. Other complications are the occlusal vertical dimension and centric relation, even though it less, it influences the clinical outcomes[7,38].

10) BIOCOMPATABILITY

T … e
oral muc… .
Srinivasa … l
denture[20]…

11) DENTURE TEETH MOVEMENT

In both conventionally fabricated and CAD/CAM … s
have been evaluated and concluded that all dentures ex… n
monolithic CAD/CAM and the greatest movement was noted in the compression method.

12) MA…
…ificantly
less than … reatment
time alone without including the time and effort spent on making clinical records, laboratory communication, and digital preview approval[7,11,38].

The current cost for the laboratory and materials is more than the conventional method[7,11].

DIGITAL DENTURE SYSTEMS :

The digital fabrication denture systems include the AvaDent, Whole You Nexteeth system (Formerly DENTCA), Wieland Digital Denture (Ivoclar digital denture), AMMAN GIRRBACH AG which combines with Ceramill Full Denture System (FDS) to provide Vita VIONIC & Baltic Denture Systems (BDS), DENTSPLY dentures

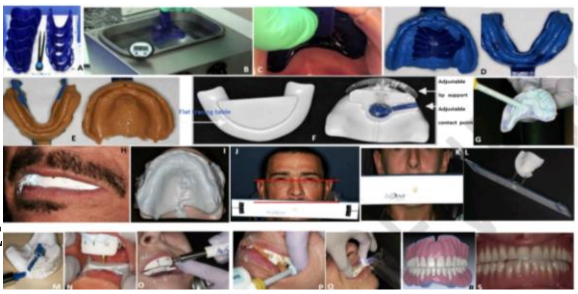
1) AVADENT DIGITAL DENTURES

The AvaDent system uses subtractive manufacturing and computer-aided engineering (CAE) which was fabricated in 2 ways.

a) The teeth will be bonded to the milled denture base

b) The teeth and the milled denture base will be made as a single unit (XCL)

Furthermore, it is also available in XCL-1 (monochromatic teeth) and XCL-2 (polychromatic teeth)[46]. In this system, the jaw relation records are obtained by either from duplicating the patient's existing denture or from the prefabricated tray or Good fit denture trays or by conventional method. Then, the definite impressions are sent to the manufacturer. If the clinician does no longer feel cozy having the dentures fabricated without assessing phonetics, esthetics and function, a try-in denture can be ordered[45]. Then the milled denture is adjusted intraorally and delivered. Including try in, it will be completed by three appointments[20, 33,43].



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)

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)

Source: Moaleem MM, Al-layl OA, Alhomood MA, Ageeli WA, Qsadi AA, Mohammed TI, Baraqt ES, Zubayni B, Alalmaie NI, Huraysi AH. Computer engineering complete dentures workflow: Systematic techniques review. Journal of Pharmaceutical Research International. 2021 Dec 4;33(53A):207-20.

2) WHOLE YOU NEXTEETH SYSTEM (Formerly known as DENTCA)

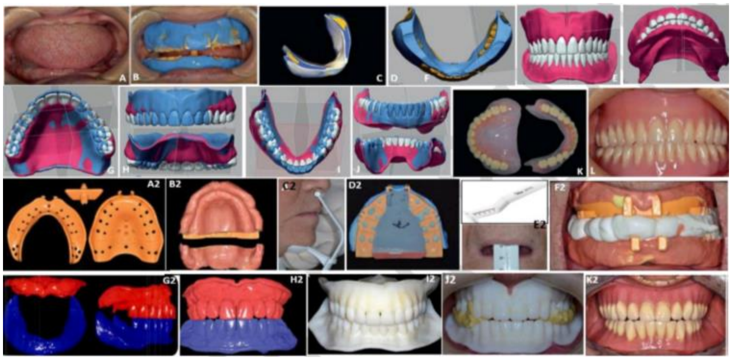
The DENTCA also fabricated in 2 ways, which use additive manufacturing.

a) Using a custom 3D printed flask, printed trial denture will be processed traditionally.

b) Printed denture base and denture teeth are bonded by a 3D printer[15].

It consists of two piece trays where the posterior segment can be detached and the anterior segment can be used as a guide for jaw relation records, interocclusal records, distance from incisive papilla to the upper border of the upper lip are recorded and also impressions are made using heavy and light body PVS material. These records are scanned and articulated digitally. These are sent to clinicians and adjustments are done wherever needed and fabricated conventionally[20,33,43].

It needs two appointments and may require additional appointments for trial denture[20].



3) AMANN GIRRBACH AG

The AMANN GIRRBACH AG uses the Ceramill Full Denture System and merged with Vita and Merz to deliver 2 workflows such as The Vita Vionic and the Baltic Denture System[20,33].

3.1 CERAMILL FULL DENTURE SYSTEM

The definite impressions are sent to laboratory for fabrication of record bases. After that, VDO, smile line, canine position and face bow transfer are recorded using that bases and sent to the laboratory. These recordings are transferred and mounted and then scanned by the software. The calculation algorithms are processed by the software for tooth arrangements, tooth line, ridge midline. Here, the esthetic template are digitized and processed for aesthetically demanding patients[16]. The milled teeth and denture base are integrated and processed in a wax base. Then sent to the clinician for approval and adjustments are made for esthetic correction, phonetic correction, smile line, lip line and processed conventionally[20,33,43,44].

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 imag

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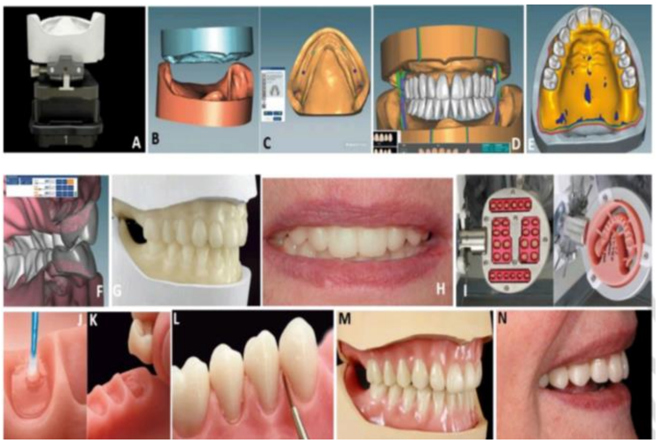
Mounted master ca casts in CAD sof lla (Fig. 5D2), and for mandible (Figure 5E2), Artificial teeth arrangement (Figure 5F2), in Maxilla (Fig. 5G2), and arrangement in scar on of artifici icial teeth (es in articul plete dentur

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), 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)

Source: Moaleem MM, Al-layl OA, Alhomood MA, Ageeli WA, Qsadi AA, Mohammed TI, Baraqt ES, Zubayni B, Alalmaie NI, Huraysi AH. Computer engineering complete dentures workflow: Systematic techniques review. Journal of Pharmaceutical Research International. 2021 Dec 4;33(53A):207-20.

3.2 VITA VIONIC

Like Ceramill Full Denture System, this was also designed but here the denture teeth and the base material were put together by Vita[20,33].



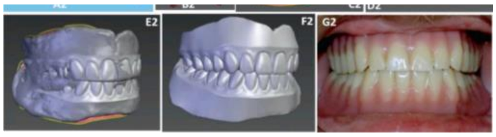
Mandibular BD Key (A), Maxillary BD Key (B), and both keys click-fixed together (C), High congruence between milled CAD/CAM denture base and master cast. Green = maximal concordance; turquoise and yellow = less concordance. Maxillary and mandibular definitive impressions (Figure 4A2), Stereolithography (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)

3.3 B

AH. Computer engineering complete dentures workflow: Systematic techniques review. Journal of Pharmaceutical Research International. 2021 Dec 4;33(53A):207-20.

In ... ng the maxillary a ... thetic, functional components and jaw relation records are taken using a special device called KEY LOCK. Then the software generates the data and tryin is performed in the first sitting itself. The acquired data is processed and delivered in the second appointment[20,33,43].

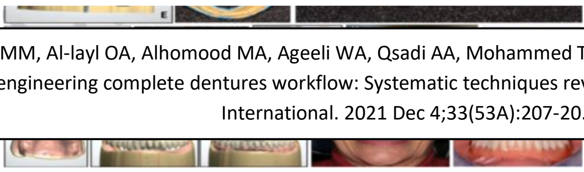
Centric Tray®, Recording of preliminary inter-arch report with the Centric Tray® and high viscosity elastomer, UTS CAD® (A-B), UTS CAD® device connected to the Centric Tray® for recording deviations from reference planes (C), Maxillary and mandibular individual milled tray (D), Values of UTS CAD® device 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 areference 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)



4) WIELAND DIGITAL DENTURE (Wieland dental + Technik Ivoclar Vivadent)

It also uses a subtractive technique for the fabrication of denture. This system requires 3 or 4 appointment workflows. The definite impressions are taken in a preformed trays and camper line, smile line, interpupillary line, interocclusal records and face bow records are taken in a provided device and sent to the laboratory. Using the software, these records are scanned and the occlusal plane determined. The denture teeth are selected from the software library and arranged and then bonded to a definite denture. These virtual setups are modified according to the clinician and/or patient's need. If the clinician demands a trial denture, it would be sent and adjusted accordingly. Otherwise the denture will be milled and delivered for insertion[20,33,43].

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



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5) DENSTPLY SIRONA DENTURES

It is the most recent denture system. Here the denture resins are specifically made and fixed using light polymerizati

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ADVANTAGES AND DISADVANTAGES OF CAD/CAM COMPLETE DENTURES :

Advantages of digital fabrication denture systems:

- ❖ Lesser appointments[20,33]
- ❖ Reduced polymerization shrinkage[20,33]
- ❖ Decreased residual monomer[20,33]
- ❖ Lesser fabrication time [20,33]
- ❖ Superior quality of dentures preventing microbial adhesion[20,33]
- ❖ Easy reproduction of the tissue architecture[20,33]

Disadvantages/ Limitations of digital fabrication denture systems:

- ❖ Defining the mandibular occlusal plane is difficult[20,33]
- ❖ Needed a lavish setup, thus increasing laboratory costs[20,33]
- ❖ Expensive materials charges[20,33]
- ❖ Mostly lack trial denture try in[20,33]

CONCLUSION:

In conclusion, Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) technology has significantly advanced the field of complete denture fabrication. The precision, efficiency and customization offered by CAD/CAM systems not only enhance the accuracy of denture construction but also contribute to improved outcomes in terms of fit, aesthetics and patient satisfaction. As technology continues to evolve, integrating CAD/CAM into complete denture workflows holds great promise for enhancing the overall quality of dental prosthetics.

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