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|  <p>ISSN NO. 2320-5407</p> | <p>Journal Homepage: www.journalijar.com</p> <h2 style="text-align: center;">INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)</h2> <p style="text-align: center;">Article DOI:10.21474/IJAR01/11780 DOI URL: http://dx.doi.org/10.21474/IJAR01/11780</p> |  <p>INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR) ISSN 2320-5407 Journal Homepage: http://www.journalijar.com Article DOI:10.21474/IJAR01/11780</p> |
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RESEARCH ARTICLE

REJUVENATING EDENTULISM USING CAD-CAM TECHNOLOGY: A COMPREHENSIVE REVIEW

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Manuscript Info

Manuscript History

Received: 25 July 2020

Final Accepted: 28 August 2020

Published: September 2020

Key words:-

CAD-CAM, Milling, Digital Intraoral
Impression, Edentulism, Complete
Denture

Abstract

Edentulism has been a severe public health problem in industrialized countries due to aging and poor oral care. Design and fabrication of the complete dentures are mainly using conventional methods involving an enormous series of clinical and laboratory procedures. Edentulous patients have to make several visits to the clinic for the traditional fabrication of denture. Now the unceasing developments occur over several years. Present-day technological innovations allow the use of various systems with computer-aided design/computer-aided manufacture (CAD/CAM) technology to produce complete dentures has seen exponential growth. There are different manufacturing techniques of CAD-CAM complete denture like AvaDent, Wieland digital denture, Baltic denture, DENTC system. CAD-CAM technology requires only two appointments for the patient to get their complete removable denture. A reduction in clinical chair time also shortens the cost of care. The improved fit of the denture was because of fewer processing errors. It simplifies the re-manufacturing of lost/broken prostheses due to the digital storage of denture data. The pre-polymerized acrylic resin used by manufacturers for the fabrication of a denture base delivers excellent fit and strength when compared to conventionally processed bases. It doesn't show any polymerization shrinkage as there is a less residual monomer. Hence, it reduces the potential infections as fewer candida albicans attach to the denture bases. The motive of this article is to highlights the benefits of CAD-CAM technology over conventional denture fabrication.

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Introduction:-

The absence of natural teeth disturbs people's lives in a physical and psychosocial way. The change in oral health condition, mainly the absence of natural teeth, often reduces essential daily oral activities. These include the capability to masticate and communicate, as well as a reluctance to appear in society. In contrast, dentures can improve appearance, speech, and function, ensuring more self-confidence and involvement in social activities. Complete dentures have been the primary treatment for edentulous patients for decades. However, the procedure of making conventional complete dentures can occasionally be complicated and necessitates various steps. Moreover, dimensional change in the polymers throughout the denture processing may lead to compromised fit. Recently, digital dentures have become more renowned and accepted in dentistry.¹

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In dentistry, we have a long history of developing the desires of the patient by contributing to the restorative and prosthetic devices such as inlays, onlays, crowns, fixed partial dentures, implant abutments/prostheses and maxillofacial prostheses to recover patient's oral function and maintain their health.²

After nearly 80 years of minimally modified systems and protocols to fabricate complete dentures, the first commercially accessible computer-aided design/computer-aided manufacturing (CAD/CAM) denture systems indicated a novel era in removable and fixed prosthodontics.³ Poly-methyl methacrylate (PMMA) was the last of the materials developed in the 1930s. By the 1940, this material was used to make 90 to 95 % of all the dentures.⁴ During the past decade, prosthetic dentistry was extremely impacted by computer-driven technologies, which has also touched upon the rehabilitation of edentulous patients.⁵ In dentistry, the significant developments of dental CAD/CAM systems occurred in the 1980s. The fabrication of complete dentures by CAD-CAM methods has become widespread in clinical and laboratory practices in recent years. This enhanced popularity may be associated with improvements in the CAD-CAM techniques and the increasing awareness of clinicians and laboratory technicians. Also, increased flexibility is helpful to unite parts of the digital workflow with standard clinical and laboratory protocols.⁶

Three pioneers in specific contributed to the advancement of the current dental CAD/CAM systems. Dr. Duret was the first in the arena of dental CAD/CAM improvement. Later he established the Sopha System, which influenced the later development of dental CAD/CAM systems globally. The second is Dr. Moermann, the developer of the CEREC system. He attempted to use new expertise in a dental office clinically at the chair-side of patients. The emergence of this system was innovative because it allowed same-day ceramic restorations. When this system was published, it quickly spread the term CAD/CAM to the dental profession. The third is Dr. Andersson, the inventor of the Procera® system.² His pioneering activities became commercially available as the Procera method of fabricating crowns in 1983. The Procera system was subsequently acquired by Nobel pharma (now Nobel Biocare) in 1988.⁷

To get conventional complete dentures, edentulous patients usually have to make five visits to the dental clinics for preliminary impressions, final impressions, recording jaw relations, a trial of the wax denture, and insertion of complete dentures. The clinical and laboratory procedures performed manually.⁸ However, CAD-CAM denture system patients are required to spend less time in clinics and make fewer visits.⁹ Also, it requires less time for laboratory personnel work.¹⁰ Baba et al. summarized the commonly available digital methods for both complete and partial dentures. He reviewed the step-by-step procedures for the fabrication of complete digital dentures. A more recent review discussed four systems available to practitioners for the fabrication of CAD/CAM complete dentures.¹¹ These systems are existing for the construction of CAD/CAM dentures: AvaDent denture system, Wieland Digital Denture, Baltic Denture System, DENTCA (Whole You) system.

This article aims to review the different systems available for the fabrication of CAD/CAM complete dentures.

Manufacturing techniques:

AvaDent:

AvaDent was created by Global Dental Science (the ground-breaking company) in 2011 by an international team of leaders in digital dentistry. Two appointments are sufficient for the fabrication of AvaDent dentures. If the clinician wants to order a try-in denture to assess phonetics, function, and esthetics, then the AvaDent complete dentures can be completed in 3 appointments.

The AvaDent system having two types of denture:

The first type is a milled denture base with bonded teeth.

The second type is a monolithic prostheses.

In monolithic prostheses, the AvaDent extreme cross-linked (XCL) teeth and the base are present as a single unit. According to Avadent XCL teeth, it further classified into two types:

1. The XCL-1 denture has a single-layer tooth which has a dentine core.
2. The XCL-2 denture has a multiple-layered tooth which has a dentin and enamel core with natural morphology.¹²

The Avadent system offers the possibility to produce complete dentures, record bases, single arch dentures, immediate complete dentures, provisional dentures, occlusal lock splints, radiographic guides, verification jigs, bone reduction guides, conversion dentures, obturators, and definitive hybrid prostheses.¹¹

Procedures:

In the Avadent system, a definitive impression can be taken with existing dentures so a preliminary impression is not required. The system also has prefabricated trays that can be adjusted and border molded using a polyvinyl siloxane (PVS) material. Definitive impressions are made using a light-body PVS impression material. Firstly, mix the 2 part heavy-consistency polyvinyl siloxane and press it into the existing denture to make a PVS cast. Make a definitive impression with the impression materials and thermoplastic moldable trays (figure.1) which are available in different sizes.¹³



Figure 1:- Avadent stock trays.

Evaluate the tray intra-orally to confirm it covers all the proper anatomic areas and alter the borders as needed.¹³ The thermoplastic tray is become softer by dipping it into a hot water bath at 80°C (170°F) for about 1 minute and then adjust the tray to the putty cast by pressing the material into contact with the cast or extending the material to cover required areas. The adapted trays can then be adjusted using acrylic resin burs to remove overextended areas.¹⁴

Adapt the trays on the putty cast. Then they are placed in the patient's mouth. It determines the regions of overextension or underextension and made needed adjustments. The maxillary tray must extend posteriorly to cover the area of the vibrating line and the hamular notches. It is also crucial, the mandibular tray cover the retromolar pads, the buccal shelves, and available regions of the lateral throat form (retromylohyoid area). Coverage of the appropriate maxillary areas requires determining the location of the vibrating line by having the patient pronounce the word "ah" or by coughing and by palpation of the distal aspect of the tuberosities to locate the hamular notches. Defining the extension of the mandibular tray needs visually noticing the retromolar pads and reflecting the cheeks to localize the extent of the buccal shelves. Assessment of the retromylohyoid areas needs placing the head of a dental mirror into these regions and asking the patient to wet the lips with the tongue to accomplish the degree of displacement of the mirror by the tongue musculature.¹⁴

For recording the jaw relation, a separate device, the anatomic measuring device (AMD) was used. The AMD comprises of a mandibular partial arch tray with a flat tracing table and a maxillary partial arch tray that has a centrally adaptable contact point that supports as the central bearing pin for Gothic arch tracing and an adjustable lip support flange¹¹ (figure.2). The AMD can be adjusted to establish the required occlusal vertical dimension (OVD).¹⁵ The AMD is also used to determine the precise amount of upper lip support, the position of the maxillary six anterior teeth and the required mediolateral orientation of the occlusal plane.¹⁴

Choose the precise size of the AMD (1 of 3 available sizes) by using the caliper to measure the broadest part of the residual ridge. If the residual ridge is smaller in size then use the smaller size of AMD. With the existing dentures in the mouth evaluate the occlusal vertical dimension and rest position with a preferred evaluation method.¹⁶

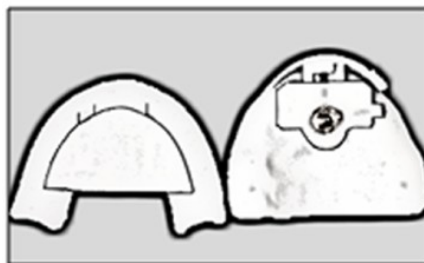


Figure 2:- Mandibular AMD with tracing plate and maxillary AMD with stylus.

There is a ruler which is used for occlusal plane orientation that can be inserted into the maxillary AMD and used to record the orientation of the maxillary AMD with the interpupillary line (IL) so that the computer program will be able to align the maxillary teeth with the interpupillary line (IL).¹⁴ The AMD of the maxilla is filled with registration material (figure 3). The system provides the material to be placed to record the morphology of the ridge and the portion of the palate that is covered by the material. The recording plate that is attached to the mandibular tray is then filled with recording material. This is done for the stabilization of the tray in the mouth of the patient. Thus, we have now achieved in determining the vertical dimension.¹⁷ If the existing dentures offer a suitable occlusal vertical dimension then they can be used to record the distance between guiding marks on the face when the dentures are in occlusal contact. If not, use conventional methods to determine the desired dimension. The rest vertical dimension, facial proportions, tonicity of the musculature, speech, and biofeedback can be used to confirm the proper occlusal vertical dimension.¹⁴ The gothic arch tracing is made by training the patient to move his/her lower jaw forward and backward while keeping contact between the maxillary stylus and the mandibular AMD tracing plate.¹⁴



Figure 3:- Maxillary AMD filled with recording material.

Protrusive and lateral mandibular movements are made by the patient to record Gothic arch tracing. The apex of the gothic arch tracing resembles an arrow and represents true centric relation. A round acrylic resin bur is used to produce a small depression at the apex of the arrow then the mandible is guided until the pin fits in the created depression. Then an inter-occlusal registration material is injected between the maxillary and mandibular AMD trays to secure them together.¹² Send both the completed impressions and the final AMD to the laboratory for scanning the jaw relation and fabrication of the dentures.¹³

Inspect the digital preview virtual setup (Figure.4) referred by the laboratory. Adjust the design of the denture if necessary.¹³ If the clinician does not feel comfortable with the fabricated dentures without assessing phonetics, esthetics, and function then he can order for the try-in denture. Two types of the try-in denture are available: i) an advanced try-in denture, which is a milled base with recesses into which denture teeth are secured with wax ii) an all-resin milled bio-functional trial denture that is available in multiple teeth shades.¹² The denture base is milled to fit the denture teeth which bond to the denture base using a bonding mechanism once the denture design is done.¹⁷ (Figure.5)



Figure 4:- Digital preview of the complete dentures.

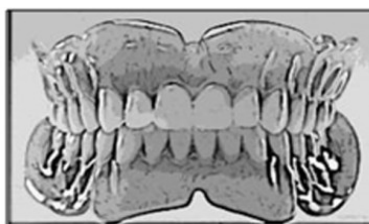


Figure 5:- Definitive AvaDent digital complete denture.

Advantages of Avadent system:

1. look authentic, providing great esthetic because of extreme cross-linked teeth
2. fit perfectly in the mouth
3. do not cause pain or discomfort.

Wieland Digital Denture:

Wieland digital denture (Ivoclar Vivadent Inc., Amherst, NY) uses subtractive manufacturing for the fabrication of their dentures.¹¹ This system is composed of a five axis-milling machine combined with a laboratory scanner and design software (3shape).¹⁸ This system can only run for completely edentulous patients. Three clinical sessions are needed for the fabrication of removable dentures using this system.¹²

The system allows for three methods to obtain clinical records:¹¹

1. Digitally designed and customized impression trays with united bite plates
2. Digitally designed and milled customized wax rims
3. Duplicated existing dentures.

During the first clinical session of denture design, preliminary maxillary and mandibular impressions are made with edentulous trays and adjusted in the patient's mouth using a poly (vinyl siloxane) impression material. Centric Tray is used for preliminary bite taking which is a simple yet effective method.¹¹ (Figure.6)

The preliminary centric relation (CR) record and vertical relationship are recorded using a centric tray record. This data forms the idea for the fabrication of the customized impression trays with integrated bite plates.¹¹ At this stage, a UTS CAD device is attached to the handle of the centric tray. (Figure.7) The basic bow assists the dentist in measuring Camper's line (the angle of the occlusal plane concerning Camper's plane) and the interpupillary line. The orientation of the occlusal plane can be read from the measurements obtained from the CL and IL scales. The preliminary impressions, centric tray, and the CL and IL measurements are sent to the laboratory technician.¹²

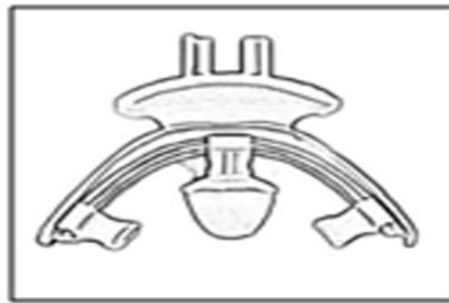


Figure 6:- Centric tray.

In the laboratory, the dental technician scans the preliminary impression and then interocclusal record. The camper line and interpupillary line values are also entered in the design software that produces virtual models of the edentulous jaws and determines the patient-specific occlusal plane.¹²

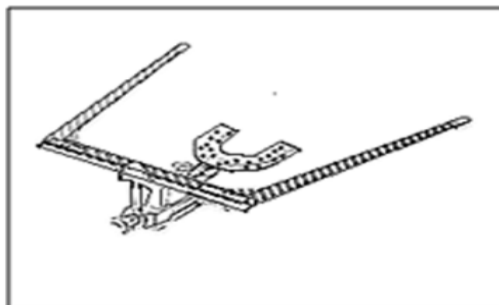


Figure 7:- UTS.

The second clinical session consists of the definitive impression that was made with PVS in custom trays. The trays were the first border molded with a heavy-body PVS (Virtual Heavy Body; IvoclarVivadent AG). The participants were asked to make lip and cheek movements until the impression material had polymerized. Then the impressions were completed with a light-body PVS.¹⁹

The occlusal plane was then re-evaluated using UTS CAD. The Gnathometer (Figure.8) is attached to the customized trays.¹¹ The occlusal vertical dimension (OVD) is determined using customary methods. The midline, smile line, and lip closure line were marked, and tooth shape and tooth color were selected. The definitive impressions were used to retain a click-on recording plate and a stylus. The vertical dimension, phonetics, facial proportions, and physiologic resting position were evaluated with the impressions in place. Centric relation was acquired by using the plate and stylus for gothic arch tracings. To stabilize the maxilla-mandibular relation, a scannable recording material (Virtual CAD bite Registration; IvoclarVivadent AG) was inserted.¹⁹

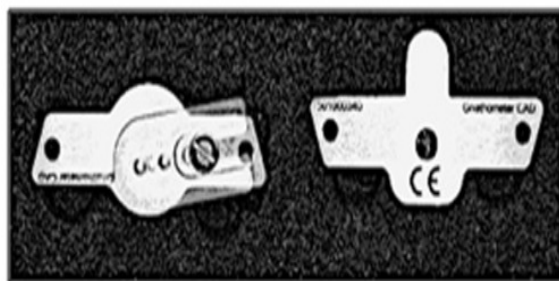


Figure.8:- Gnathometer.

The records and the functional impressions are scanned to determine the occlusal plane. At this stage, the denture teeth are chosen from the software library of denture teeth and the design program will suggest a virtual teeth setup. Following the selection of denture teeth, the program will suggest a virtual teeth set-up in occlusion taking into consideration the curve of Spee and Wilson. The teeth setup can be modified according to the demands of the clinician and patient or if no changes are requested, finalized by adding the gingival portion of the dentures. A pre-polymerized disk of PMMA is used to mill the gingival portion of the denture bases. If the clinician feels more comfortable ordering a try-in denture to assess phonetics, function, and esthetics and, if necessary, enable corrections to the try-in denture, the dental technician can mill a monolithic PMMA try-in denture.¹¹

During the third session, the acrylic trial dentures were used to evaluate fit, retention, maxillomandibular relationship, occlusion, and esthetics of the future CD. If necessary changes were discussed with the patient and corrected by the dental technician.¹⁹

Using a five-axis milling machine, the laboratory will mill the bases of the definitive dentures from a consistent pink PMMA resin disc²⁰ with specific alveoli for the prosthetic teeth, depending on the brand and model of the teeth selected (Figure.9). Thereafter, a positioning key is milled to ensure the ideal setting of the teeth during the bonding process with a PMMA resin (Figure 10). Once the bonding is complete, the disc is placed back into the machine to mill the denture intrados. The denture is removed from the disc, scraped and polished according to the conventional procedure.¹⁸

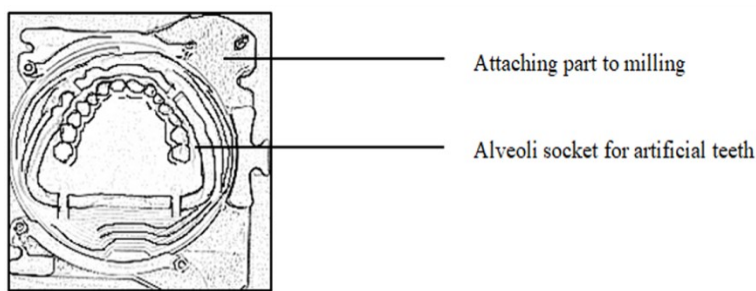


Figure.9:- Definitive CD after final milling.

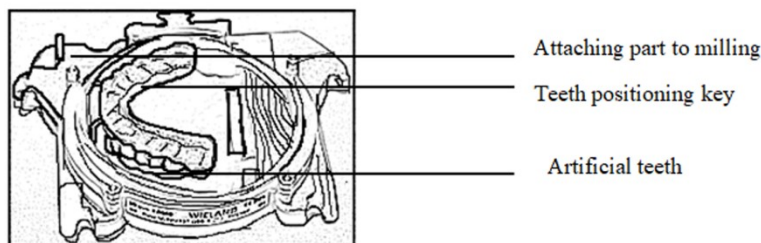


Figure.10: A positioning key is milled to ensure the ideal setting of the teeth during the bonding process with a PMMA resin

In the fourth clinical session, the CAD/CAM complete denture insertion is almost identical to the insertion of a conventionally fabricated complete denture. Pressure indicator paste is used to help the necessary adjustment in the fit of the intaglio surface to the mucosa. The occlusal adjustment might be essential and could be performed intraorally. The severe disparity in occlusal contacts between the dentures can be adjusted following a clinical remount procedure.¹¹

Advantages of Wieland digital denture:

1. Easy transfer of the accurate occlusal plane position
2. Specific transfer of the correct maxillomandibular relation and centric position
3. Time-saving customized tray design and bite registration

Baltic Denture System:

The Baltic Denture System is designed to provide patients with complete dentures in 2 appointments. The first appointment for an impression of mouth and second appointment is for full denture insertion.

Procedures:

The Baltic Denture System allows the dental practitioner to initiate the denture fabrication process using functional impressions with the help of the BDKEY Set components (Merz Dental GmbH) (Figure11). The initial components of the set include maxillary and mandibular adjustable record bases with teeth. These trays are available in 3 sizes (small, medium, and large) with different sizes and shapes of teeth. The trays are adjusted intraorally.¹² Four tissue stops (Figure 12) were incorporated in the stress-bearing areas on the inner surface of the maxillary tray using a pliable putty such as thermoplastic impression material (BD Impress) which is softened at 75–85°C and later hardens to a plastic compound at the oral temperature.²¹

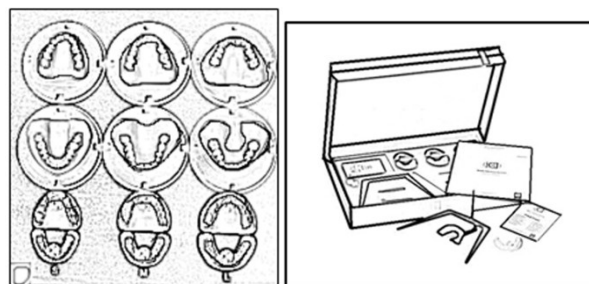


Figure 11:- The BD Key Sets corresponding to the Load Blanks of various shades and sizes.



Figure 12:- Tissue stops incorporated in the upper and lower key.

The occlusal plane analyzer (BDKEY Plane and the BDKEY Fin) (Figure13) was attached to the upper impression tray following which the occlusal plane was oriented parallel to the interpupillary line and the Camper's plane. The facial midline and anterior tooth visibility were also verified.²¹



Figure13:- BD Key plane and Fin for orientation occlusal plane.

The definitive impressions were obtained while a registered facebow that includes a vertical indicator which is attached to the maxillary tray to register the facial midline. Then transfer the esthetic and functional components from the patient to the designing software. The facebow helps the clinician to record the interpupillary line and camper line. The vertical indicator helps to record the midline. The centric lock (BD Key Lock) was used to secure the lower impression tray onto the upper tray, following the application of three tissue stops (two in the molar region and one in the anterior region). So, it aid in jaw relation records.¹²

A virtual three-dimensional model was obtained by importing the scanned data into the specialized software (BD Creator). The functional borders and reference points such as the center of the ridge, the incisal papilla, and mid-palatal suture were marked. It aids in aligning the teeth and even generating milling paths. The appropriate milling block (BD Load) size and jaw width were selected along with the teeth.²¹ The presence of teeth on the trays permits evaluation of the overall esthetics, lip support, tooth alignment, and interocclusal space. Since the BDKEY trays identically replicate the size and shape of the denture teeth in the milling blocks, they function as try-in dentures to confirm the patient's approval of the future dentures.¹²

The laboratory generates data acquisition after scanning all the records sent by the clinician. The CAD design of the accessible data is recognized using the BD Creator software (Merz Dental GmbH). After design approval, the dentures are milled in a five-axis computerized numerical control machine. The milling blanks are made of cross-linked polymethyl methacrylate (PMMA) and available in 3 different sizes. They have an integrated tooth setup in lingualized occlusion (Figure14). The anterior and posterior teeth are available in several sizes and shapes.¹² Following the milling, the dentures were separated from the blank using rotary instruments, and conventional finishing and polishing were performed. The dentures were inserted at the second appointment and minor occlusal adjustments were carried out. Overextensions of the denture flanges, if present, were altered, and the denture was finished and polished before delivery to the patient. The patients were recalled after a week and then after 6 weeks for evaluation.²¹

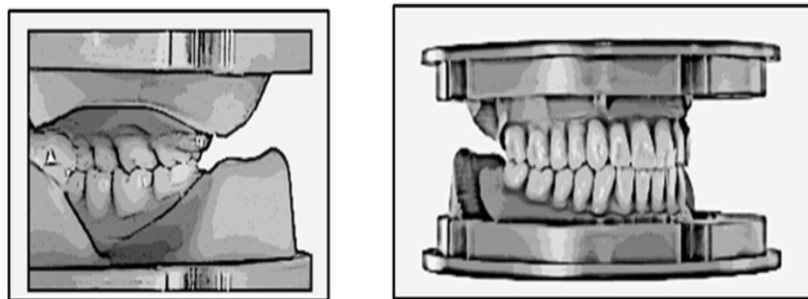


Figure 14:- Lingualised occlusion of the dental.

Advantages of Baltic Complete Denture:
Only 2 dentist appointments are required

1. Perfect fit & perfect bite can be taken
2. Lowest allergy potential
3. Plaque-free surface
4. Dentures of highest quality

DENTCA system:

DENTCA system is now solely concentrated on denture design and the fabrication of the denture trays. Whole You system, a sister company, focuses on manufacturing. When the clinician submits the definitive impressions and trays, the CAD part is completed by DENTCA and the CAM part is fulfilled by the Whole You system.¹² DENTCA system uses new cutting edge CAD/CAM technology to renovate and bring about a revolution of the complete dentures produced by this system. Research has shown advanced 3D software provides improved accuracy, produces more comfortable dentures for patients, and permits you to complete a full denture case 2.5 time faster.¹⁷

The system allows the fabrication of complete dentures using two different methods: In the first method, additive method, a trial denture is printed and verified in the patient's mouth and then traditionally processed using a custom 3D printed flask. In the second method, the denture base is printed by a 3D printer, and the denture teeth are bonded to the printed base.¹²

Procedures:

Both maxillary and mandibular Dentca stock trays are two-piece trays with the detachable posterior segment (Figure15). The appropriately sized maxillary and mandibular stock trays are selected based on the patient's arch size. The Dentca trays are used for both the final impression and also for the jaw relation records. The trays are painted with an adhesive and a heavy-body poly (vinyl siloxane) impression material used for the border molding.¹² Final impressions of the maxillary and mandibular arches are made using a light body poly (vinyl siloxane) impression material.¹⁴ Care must be taken to ensure adequate border extensions and surface detail. The detachable segments of the trays need to be removed after making the definitive impressions to record the appropriate vertical dimension of occlusion and centric relation.¹²

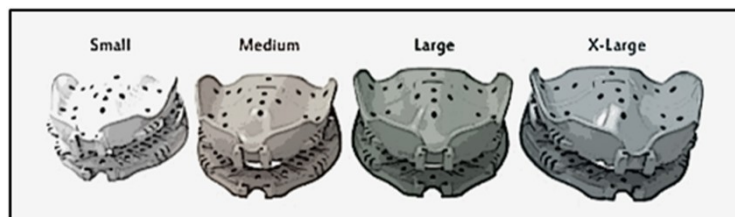


Figure15: Maxillary and mandibular Dentca detachable stock trays

A #15C surgical blade is used to detach the posterior area of the maxillary and mandibular impression trays. The anterior sections of the trays are inserted in the mouth and the central pin of the gothic arch tracing device is adjusted to achieve the VDO.²⁰

A vertical pin is attached to the mandibular impression tray, and both impression trays are placed back in the patient's mouth (Figure16). The vertical dimension can be adjusted by rotating the vertical pin clockwise or counterclockwise.¹² When finalizing the occlusal vertical dimension, the mandibular stylus should contact the maxillary tracing plate.¹⁴



Figure16: Mandibular Dentca impression tray showing the posterior segments of the tray which is detachable with the stylus used to record CR.

Once the vertical dimension is confirmed, a tracing pad (EZ-Tracer, DENTCA system) is placed on the maxillary impression tray, and both are placed back in the patient's mouth. The manufacturer suggests that CR be recorded with 1 of 3 techniques: a simplified tracing, a gothic arch tracing, or a direct interocclusal record. Once the CR point is determined, a small indentation is created with a bur to allow easy verification that the vertical pin is seated in CR. The interocclusal registration is made by locking both the maxillary and mandibular trays together while the patient is in CR. The final step involves using the provided lip ruler to measure the distance from the incisive papilla to the inferior border of the upper lip that is the length of the maxillary lip.¹¹

Also the processing of computer-aided design at the laboratory, the definitive impression is scanned using the Dentca CAD software through the source of the light (Laser) and receptor on the computer. The computer can compute the three-dimensional data from the image of the receptor unit. After recording the impression of both jaws, a three-dimensional image is produced, and then the clinician enters the data to create maxillomandibular virtual edentulous ridges by CAD software and at the same time the laboratory technician can improve the lip length, as well as teeth arrangement or set up virtually.²²

The maxillary and mandibular impressions, interocclusal record, and recorded measurements are sent to the manufacturer for denture fabrication. The records are 3D scanned and digitally articulated. Denture teeth are virtually arranged and customized. The designed denture is then 3D printed and shipped to the clinician for a try-in or used directly to fabricate the final complete dentures.¹¹

The CAD/CAM complete denture insertion is almost identical to the insertion of a conventionally fabricated complete denture. Pressure indicator paste or Fit Checker™ (GC America, Alsip, IL) are used to help make the necessary adjustment in the fit of the intaglio surface to the mucosa. The occlusal adjustment might be essential and could be performed intraorally. The severe disparity in occlusal contacts between the dentures can be adjusted following a clinical remount procedure.¹²

Advantages of Dentca system:

1. Advanced 3D software provides increased accuracy and more comfortable dentures for the patient
2. The process and make denture making even simpler and faster
3. Digital back up files allow for easy recovery
4. Duplication and remake of lost/old denture prostheses.

Conclusion:-

Fabrication of complete dentures utilizing CAD-CAM innovation has become more outstanding in the age of digitized dentistry. The article aims to review the different systems available for the fabrication of CAD/CAM complete dentures. The manufacturing clinical conceptions and techniques are diverse for each system, which simplifies the clinician's ability to select their preferred system for digital denture fabrication. The endless revolutionary vision of digital technology in the field of dentures is vital to improving the clinical and laboratory performance of denture fabrication. So, the fabrication CAD/CAM complete dentures have positive benefits for both the patient and practitioner. Nevertheless, it has several benefits such as less time-consuming, reduced resin polymerization, re-manufacturing of the lost or broken prostheses due to digital storage of denture data.

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