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Computer aided design / Computer aided manufacturing and 3D printing for fabrication of complete dentures

A graduation project submitted to the College of Dentistry/ University of Baghdad, Department of prosthodontics in partial fulfillment of the requirement for the degree of B.D.S

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بسم الله الرحمن الرحيم

يرفع الله الذين آمنوا منكم والذين أوتوا العلم درجات

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certification of the supervisor

I certify that this project entitled "**Computer aided design / Computer aided manufacturing and 3D printing for fabrication of complete dentures**" was prepared by the fifth-year student **Alia Farouk Bakr** under my supervision at the College of Dentistry/University of Baghdad in partial fulfilment of the graduation requirements for the degree of B.D.S.

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Dedication

This study is wholeheartly dedicated to my beloved parents, who have been my source of inspiration and gave me strength when I thought of giving up, who continually provide their moral, emotional and support.

To my brother, sister, and friends who shared their words of advice and encouragement to finish this project.

Acknowledgment

First of all, I want to thank **God Almighty**, for the guidance, strength, power of mind, protection and skills and for giving us a healthy life.

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Finally, I would like to thank my family for all support they have provided throughout the years of studying.

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List of abbreviations

Abbreviation	Meaning
QoL	Quality of life
CD	Complete denture
Fig	figure
ZOE	Zinc oxide eugenol
CAD	Computer aided design
CAM	Computer aided manufacturing
CEREC	Chairside economical restoration of esthetic ceramics
LCOS	Lava chairside oral scanner
PMMA	Pre-polymerized polymethyl methacrylate
3DP	Three dimensional printing
GDS	General dental services
PAR	Prepolymerized acrylic resin
UV	ultraviolet
FPD	Fixed partial denture
STL	stereolithography
IOS	International organization for standardization

Introduction

Introduction

Complete edentulism is an eventual oral health outcome and results from the combined pathology of dental caries, periodontal disease, or faulty method of rehabilitation due to reduced cost. Complete edentulism has a significant concern and leads to reduced quality of life (QoL) along with impact on general health. However, it has been observed that due to wider and better oral health services globally, edentulism rate is decreasing every decade. Edentulism is directly related to masticatory and nutritional problems, and some authors regard it as a good mortality indicator **(Kaushik et al. 2018).**

In addition to that the change in oral health status, especially the loss of natural teeth, often diminishes daily essential activities, as well as the patient reluctant to appear in public. Consequently, people may develop anxiety, decreased self-esteem and depression. In contrast, complete denture can improve appearance, speech and function, resulting in more self-esteem and participation in social activities **(Sivakumar et al. 2015)**.

Aim of the study

The aim of this project to discuss the importance of cad cam in facilitating the fabrication of complete denture and compare them with conventional method.

Chapter one

Review of literature

Chapter one: Review of literature

1. **Complete denture:** is defined as "A dental prosthesis which replaces the entire dentition and associated structures of the maxilla and mandible **(Deepak Nallaswamy et al. 2003).**

1.1 Classification of complete denture:

- Removable complete denture
- Fixed complete denture **(Deepak Nallaswamy et al. 2003).**

1.2 Function of a complete denture:

A complete denture functions to restore:

- Aesthetic: the complete denture should restore the lost facial contour, vertical dimension, etc.
- Mastication: a complete denture should have proper balanced occlusion in order to enhance the stability of the denture.
- Phonetics: one of the most important functions of a denture is to restore the speech of the patient.**(Deepak Nallaswamy et al. 2003).**

Fig 1.1: set of complete denture https://moshmandental.com/patient-services/complete-dentures-brooklyn/.

1.3 Fabrication of the complete denture

Table1.1: workflows of conventional CDs fabrication **(Mubaraki et al. 2022).**

Clinical steps	Laboratory steps
1st visit 1. primary impression	1. stone cast model 2. manufacturing the individual tray
2nd visit 2. border-modelling technique 3. final impression	3. final cast model 4. fabrication of denture base and occlusal rims
3rd visit 4. interocclusal registration	5. assembling the models in articulator 6. setting up the teeth
4th visit 5. try-in the denture	7. processing the denture 8. finishing and polishing the prosthesis
5th visit 6. delivery of the prosthesis.	

1.4 Complete denture impression: is a negative registration of the entire denture bearing, stabilizing and border seal areas present in the edentulous mouth. **(Lakshmi S 2018).**

1.5 Objectives of dental impression

The objectives of the dental impression are:

1) retention: is the resistance of the denture to forces acting in a vertical direction.

2) stability: is the ability of the denture to be firm, steady and constant and the resistance of the denture to forces acting in lateral or horizontal direction.

3) support: is the ability of the denture to resist vertical and other forces in a direction towards the basal seat.

4) esthetic and preservation of residual alveolar ridge and soft tissue. **(Lakshmi S 2018).**

Fig 1.2:

support, retention, and stability in CDs **(Al-Muthafa Azad 2014)**.

1.6 Classification of impressions

1.6.1 Impression making for complete denture consists of two steps:

1.6.1.1 primary or preliminary impression

It is a negative likeness made for the purpose of diagnosis, treatment planning or fabrication of a special tray. It is the first impression made for the patient and from which the study cast was poured.

Material used: impression compound, alginate or elastomeric putty **(Bernard Levin 1984).**

Fig 1.3: primary impression for complete edentulous patient maxillary and mandibular ridges with impression compound material **(Al-Muthafa Azad 2014).**

1.6.1.2 secondary or final impression

It is a negative likeness for the purpose of fabrication the prosthesis and from which the master cast was poured.

Material used: Zinc oxide eugenol (ZOE), alginate, impression plaster or elastomeric impression [polysulfide (rubber base), polyether, silicone (light body)], waxes **(Bernard Levin 1984).**

Fig 1.4: final impression for complete edentulous patient maxillary and mandibular ridges **(John Beumer et al. 2011)**.

1.6.2 impression techniques: (Deepak Nallaswamy et al. 2003).

1.6.2.1 Depending on pressure:

a) Mucostatic or passive impression: in this technique the impression is made with oral mucous membrane and jaws in a normal, relaxed condition. border moulding is not done here. Impression material of choice is impression plaster. retention is mainly due to interfacial surface tension.

b) Mucocompressive impression: The mucocompressive technique records the oral tissue in a functional and displaced form. The material used for this technique includes impression compound, waxes and soft liners. Dentures made by this technique tend to displace due to tissue rebound at rest.

c) selective pressure impression: In this technique, the impression is made to extend over as much denture-bearing area as possible without interfering with the limiting structures at function and rest. The selective pressure technique makes it possible to confine the forces acting on the denture to the stress-bearing areas. This is achieved through the design of the special tray in which the nonstress-bearing areas are relieved and the stress-bearing area are allowed to come in contact with the tray.

1.6.2.2 types of impression technique:

a) open-mouth technique:

The open mouth method includes the impression technique, which record the tissue in an undisplaced position. Pressure or pressurless impressions can be made using this technique.

b) close-mouth technique:

This technique records the tissues in the functional position. In this technique, record blocks (trays with occlusal rims) are used instead of impression trays.

Both upper and lower record blocks are lined with impression material and placed inside the patient's mouth at the same time. The patient is asked to close his mouth exerting pressure on occlusal rims and perform functional movements.

1.6.2.3 Depending on the material:

a) reversible hydrocolloid impression: agar

b) irreversible hydrocolloid impression: alginate

c) modelling plastic impression: compound

d) plaster impression: type I dental plaster (soluble plaster)

e) silicone impression:

- condensation polymerizing silicone

- addition polymerizing silicone

f) thiokol rubber impression: polysulfide**.**

2. Computer aided design / computer aided manufacturing

From its inception till now, dentistry has covered great milestones in terms of invention and precision to provide us with better working conditions and increase comfort for both dentists and patients **(MIYAZAKI et al. 2009)**.

The technological changes taking place over the years are truly revolutionizing the way dentistry is practiced and the manner in which dental laboratories are fabricating restoration **(Lee Culp and Alex Touchstone 2006).**

To add to the list of remarkable advancements is computer aided design (CAD) and computer aided manufacturing (CAM) technology which allows the dentist to provide special care to the patients **(MIYAZAKI et al. 2009)**.

CAD/CAM technology has become an increasingly popular part of dentistry over the past years. **(Liu 2005)**.

This technology which is used in both the dental laboratories and the dental office can be applied to inlays, onlays, venners, crowns, fixed partial dentures, implant abutments, even full mouth restorations and complete dentures. CAD CAM is also being used in orthodontics in the form of Invisalign retainers **(Rekow 1987)**.

2.1 History

Computer aided design/computer aided manufacturing were developed in the 1960s for use in aircraft and automotive industries. Dr francosis duret was the first person to develop CAD/CAM device, making crowns based on an optical impression of the abutment tooth and using a numerically controlled milling machine. He produced the first CAD/CAM restoration in 1983 **(Davidowitz and Kotick 2011)**.

Digital design and manufacturing were introduced to dentistry by Andersson, who developed the Procera system in 1983, and Mörmann, who introduced the CEREC system in 1985 **(Goodacre et al. 2012)**.

The first report of CAD/CAM use for dentures is attributed to Maeda et al, who in 1994, employed additive manufacturing technology **(Maeda et al. 1994)**.

2.2 CAD/CAM components

1. Data acquisition " scanner " under the term scanner one understands, in dentistry, data collection tools that measure three- dimensional jaw and tooth structure and transform them into digital data sets **(Mehl et al. 1997).**

2. Design softwares: are used for the designing of the final restoration which are secured in optical impression and prepared for milling parameters **(Galhano et al. 2012)**.

3. Manufacturing technologies: for the final manufacturing of the restoration with solid block of the appropriate restorative material. The first two parts of the system are associated in the CAD phase, while the third one in the CAM phase **(Galhano et al. 2012)**.

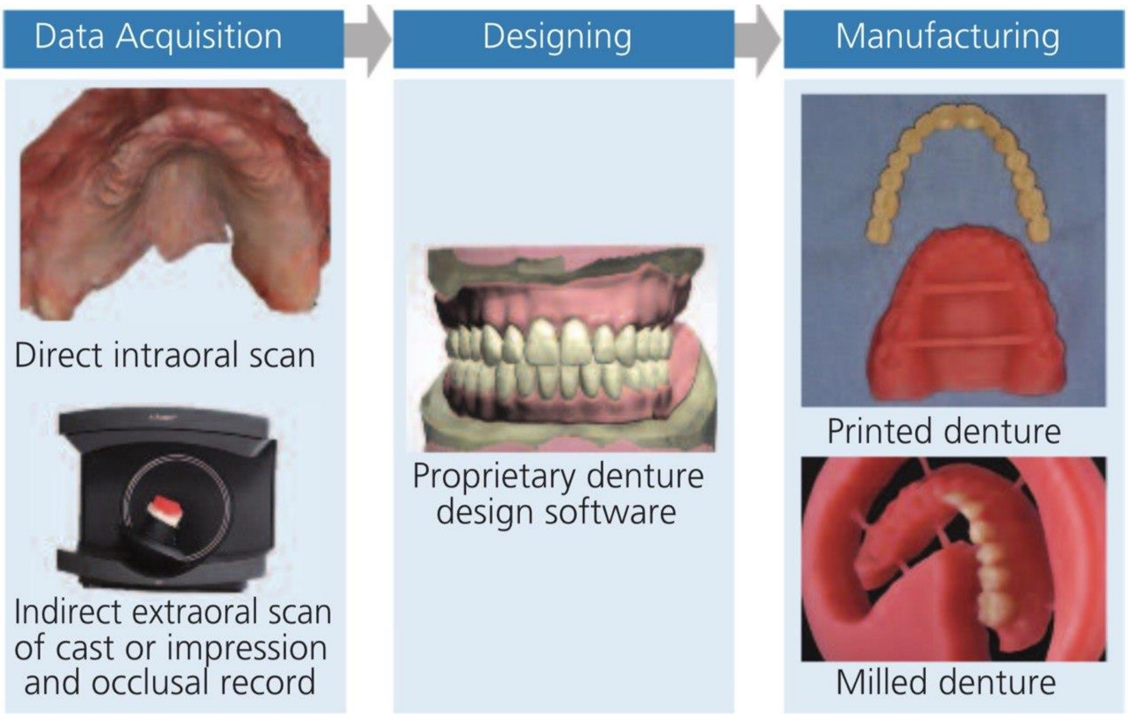

Fig 1.5: computer aided design/ computer aided manufacturing workflow **(Punj and Fisselier 2020)**.

2.3 Types of digital scanning:

2.3.1 Intraoral scanning: is performed with an intraoral scanner, thereby eliminating the requirement of a physical impression. This includes several scans of both arches requiring about 3-17 min **(Steinmassl et al. 2017)**.

IOS is a medical device composed of a handheld camera (hardware), a computer and a software. The goal of IOS is to record with precision the three-dimensional geometry of an object **(Richert et al. 2017)**.

The IOS devices use an advance optical surface scanning technology that are similarly to a camera, using the measure light reflection times from various texture through process to capture the object three-dimensionally instead of simply capturing lights and colors in the camera. The information is then captured by the 3D software that uses specific alignment algorithms to allow for registration of the object, so the most common scanning principles:

1- Triangulation

2- Active wave-front sampling

3- Parallel confocal laser scanning **(Gayathridevi et al. 2016)**.

2.3.1.1 The main intraoral digital impression systems:

- CEREC
- LCOS system
- iTero
- E4D
- TRIOS

They vary from each other in terms of key features such as working principle, light source, the necessity of powder coat spraying, operative process and output file format **(Ting-shu and Jian 2015)**.

Fig 1.6: Different types of IOS Device **(*Bayou State*, 2019)**.

TRIOS SYSTEM:

A new type of intraoral digital impression system, TRIOS, was introduces in 2010, by 3shape (Copenhagen, Denmark) and was presented to market in 2011. This system works under the principle of ultrafast optical sectioning and confocal microscopy **(Silvia Logozzo et al. 2011)**. They maintain a fixed spatial relation of the scanner and the object being scanned and recognize variations in focal plan of the pattern over a range of focus plane. Moreover, they have a quick scanning speed of up to 3000 images per second thereby reducing the influence of relative movement between scanner probe and teeth.

Similar to iTero and E4D systems, the TRIOS intraoral scanner is a powder- free device in the scanning process.

TRIOS include two parts: TRIOSR cart and TRIOSR pod. The TRIOSR pod is having a handheld scanner which offers better flexibility and mobility, so due to its simple construction it is compatible with other computers and ipad also **(Persson et al. 2009)**.

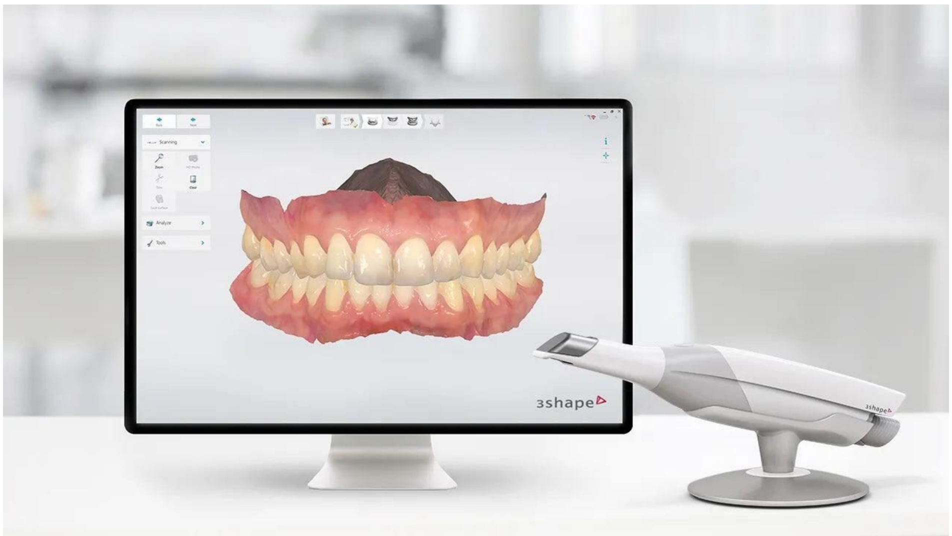

Fig 1.7: 3shape TRIOS 3 intraoral digital impression system for cad / cam (***Bayou State*, 2019**).

2.3.1.2 Advantages and disadvantages of intraoral digital impression

Advantages: In general, taking a digital impression has many advantages, including the possibility of performing an immediate chairside analysis (e.g., to evaluate the anatomy, residual ridges, presence of undercuts, or necessity of preprosthetic surgery). This approach saves on impression material and can be quicker than a conventional impression (two minutes for the maxilla, and five minutes for the mandible when possible). In addition, it is convenient in cases involving patients with a gag reflex or limited opening. It is a true mucostatic impression; in addition, there is no need for disinfection, it has a faster turnaround time, and the data can be archived for future use without occupying physical space **(Amit Punj and Francois Fisselier 2020)**.

Disadvantages: This technology has some challenges, such as the initial high cost, learning curve, and possible subscription fees for the equipment and software. Clinically, using an intraoral scanner for edentulous patients can be tricky. The posterior palatal seal in the maxilla and complicated floor of the mouth anatomy — with interference from the tongue and saliva in the mandible — can be difficult to capture. In cases with a limited amount of keratinized tissue, the mucosa is more movable and needs to be recorded in one pass since returning later over a missed area results in a different position of the soft tissue, leading to an error in the digital impression.

Hence, it is advisable to make a conventional impression and scan the impression or master cast **(Amit Punj and Francois Fisselier 2020)**.

2.3.1.3 Manufacturing technologies:

a) close × open systems

The three stages related above, despite being inter-related, may be performed in an open or close system. If **close** systems are used, the manufacturer presents equipment capable of performing each of the stages in a sequential and inter-related manner. In these cases, there is greater coherence in data processing in all stages. (e.g., Procera and Lava systems). Initially, the systems were developed in this manner; that is to say, the manufacturer presented the technology for all the stages. With the advancement in technology, tools began to be established for each of the stages in an independent manner, making it possible to integrate different scanners/software and milling machines. When the data acquisition process may be sent to any data processing center for designing and machining the indirect restoration, it is called an **open** system. There is a trend to digitalize the data in a standard template library system, and thus, any CAM system that accepts STL files can produce the indirect restoration **(Helvey 2006)**.

Open system creates more opportunities for laboratories that are capable of customizing the configuration **(Dennis J. Fasbinder 2012)**.

b) subtractive × additive manufacturing

subtractive manufacturing (milling): in the subtractive approach, a puck (block) of material is milled by automated control of specialized cutting tools that receive information from a computer algorithm known as computer numerical control technology. As the block of acrylic resin comes prepolymerized, there are no shrinkage issues. Also, as the puck is prepolymerized under high temperature and pressure, there may be less monomer release, which, in turn reduces irritation to the soft tissue. The precision of milling is directly related to the milling unit's number of axis and size of burs. The reported precision is between 5 and 25 microns. **(Alharbi et al. 2017)**.

Processing / milling devices are categorized by means of the number of milling axes: (Chris McMahon and Jimmie Browne 1998)

- 3-axis device
- 4-axis device
- 5-axis device

a) 3-axis milling devices: three axes milling device has degrees of movement in the three spatial directions. The milling points are defined by the X-, Y-, Z- values. A milling of subsections, axis divergences and convergences are not possible. This requires a virtual blocking in such areas of milling block.

The advantages of 3 axes milling devices are short milling times and simplified control by means of the three axes. Hence, such milling devices are usually less costly compared to those with a higher number of milling axes.

Examples of 3-axis milling devices are: in lab (Sirona), Lava (3M ESPS), Cercon brain (Degu Dent).

b) 4-axis milling devices:

In four axes milling devices, addition to the three spatial axes, the tension bridge rotationis included as the fourth component. Hence it is possible to adjust long span bridges with a large vertical height displacements and it also facilitates in saving material and milling time compared to three axes milling devices.

Example: Zeno (Wieland-Imes).

c) 5-axis milling devices:

With a 5-axis milling device there is, in addition to the four spatial dimensions, rotating the milling spindle is included as 5th axis. This facilitates the milling of complex anatomies with subsections, for example, lower jaw FPDs with converging abutment teeth (end molar tipped towards the medial plane, or also crown and FPD substructures that, as a result of anatomically reduced formation, demonstrate converging areas in the exterior of the framework.

Example in the Laboratory Area: Everest Engine (KaVo).

The quality of the restoration need not necessarily increase with the number of milling axes. The increased number of milling axes provides benefit only in terms of fabricating complex restorations and not relating to the quality of the restoration. The quality of restorations is more from the result of the digitalisation process, data processing and production process than the milling devices.

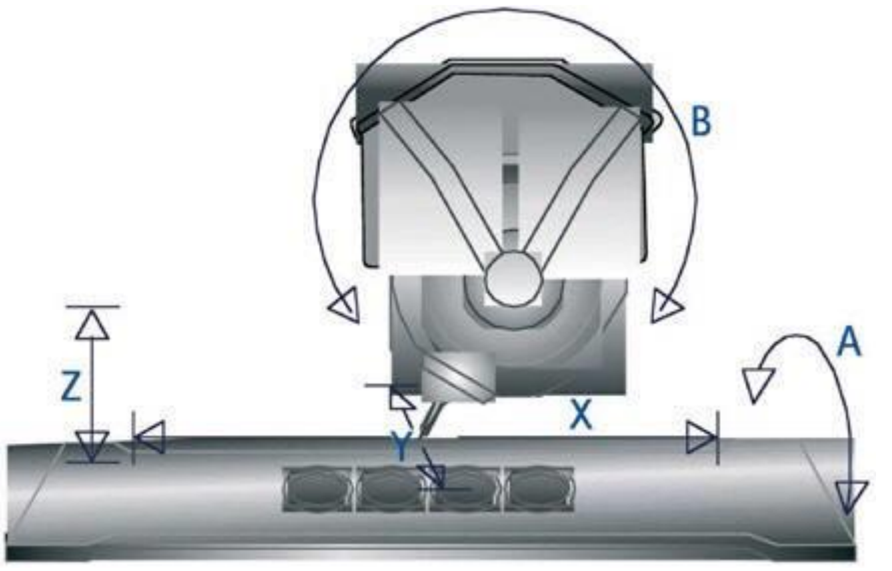

Fig 1.8: Different possibilities of the working axis: 3 spatial directions X, Y and Z (3 axis milling devices); 3 spatial directions X, Y, Z and tension bridge A (4 axis milling devices); 3 spatial directions X, Y, Z, tension bridge A and milling spindle B (5 axis milling devices) **(Beuer et al., 2008).**

Types of milling blocks: (stomadentlab.com)

1) Monolayer disc: double layer disc allows to fabricate monolithic removable denture by mean of an efficient digital workflow. Complete dentures are milled from one disc in one uninterrupted process.

Benefits:

- High quality pre-polymerized polymethyl methacrylate (PMMA) tooth and denture base materials
- Only a few manual working steps
- Innovative 3D tooth and denture base combined in one disc.

Fig 1.9: monolayer PMMA disc[https://www.dentallaboratorio.com/product-category/dental-lab-milling-supplies/dental-pmma/.](https://www.dentallaboratorio.com/product-category/dental-lab-milling-supplies/dental-pmma/)

Fig 1.10: cad /cam dental PMMA blocks designed with pink and A2 shade together https://www.dentallaboratorio.com/product-category/dental-lab-milling-supplies/dental-pmma/.

2) Multilayer blocks: The disc is fixed in disc holder in the milling machine. After milling the denture, it is separated from the disc with standard grinding tools. Artificial teeth are attached on denture base with PMMA resin or light curing composite material according to manufacturer's instructions.

3) Benefit:

- Low frication
- Fatigue resistance
- Low moisture absorption
- Excellent dimensional stability

Fig 1.11: multilayer PMMA pink baseplate disc: https://www.cm-medical.com.au/collections/cad-cam-milling.

Fig 1.12: denture teeth are milled separately from tooth colored multilayer PMMA to precisely fit within the custom-milled denture baseplate https://stomadentlab.com/.

Advantages of the subtractive method: The subtractive method tends to provide more homogenous objects with acceptable accuracy that may be suitable for the production of intraoral prosthesis where high occlusal forces are anticipated. A similar results was shown by Kalberer et al, who reported that CAD/CAM milled CDs were better than 3D printed CDs in terms of denture adaptation **(Wang et al. 2021)**.

Disadvantages of the subtractive method: The main disadvantage of the subtractive techniques is the waste, as a large portion of the block remains unused and is discarded during this process.

Another limitation is the unesthetic teeth, which AvaDent has overcome in their XCL-2 denture by using a unique layering system resulting in polychromatic teeth that stimulate the dentin and enamel of natural teeth, providing premium esthetics **(Anadioti et al. 2020a)**.

The milling process can be affected by the size of the milling bur, the characteristics of the area to be milled, and the machining axis. Therefore, different milling machines can influence the accuracy of the denture, which also explains why the denture adaptation varies among different CAD/CAM complete denture systems **(Nah 2016)**.

Additive manufacturing (three-dimensional printing):

In this method, material is stacked layer by layer, one over the other, to create a 3D structure **(Alharbi et al. 2017).**

Advantages: additive method offer various advantages over the traditional subtractivr (milling) method.

The additive technology allows manufacturing of an object regardless of its dimensional complexity and quantity. Material waste can be reduced to 40%, and details finer than the milling bur size can be fabricated **(Alharbi et al. 2017)**.

Disadvantages: with 3D printing, the build direction (layer orientation) affects the mechanical properties of the dental restorative material. This is due to nature of incremental layers in additive manufacturing technology, which may initiate crack propagation and result in a structural failure of the printed material **(Puebla et al. 2012)**.

Layer orientation was found to affect the compressive strength of 3D-printed composite material **(Wang et al. 2021)**.

Also, it is important to understand that the bond between the layers is weaker than that within the layer. This is explained by the number of residual stresses and porosities that accumulate during UV polymerization and material shrinkage **(Singh 2009)**.

The 3DP technique uses unpolymerized resins, repetitively layered on a support structure and polymerized by an ultraviolet or visible light source. Once processed, an additional light-polymerization step is required to complete the process, and polymerization shrinkage is theoretically possible during the 3DP workflow **(Kalberer et al. 2019)**. Current limitations include elimination of try-in appointment without reliable virtual esthetic evaluation, lack of retention with printed polymers requiring to reline for clinical acceptability, inability to balanced occlusion that may compromise denture stability or potentially affect bone resorption, and long-term color instability that leads to esthetic deterioration **(Anadioti et al. 2020)**.

The accuracy of printed objects can be influenced by factors including light intensity, direction and angle of printing, the number of layers, software, and shrinkage between layers, the amount of supporting structure, and the post-processing procedures **(Yuzbasioglu et al. 2014)**.

Recently recommended usages for 3D printed complete dentures are interim or immediate dentures as well as custom tray or record base fabrication for conventional workflows. **(Anadioti et al. 2020)**.

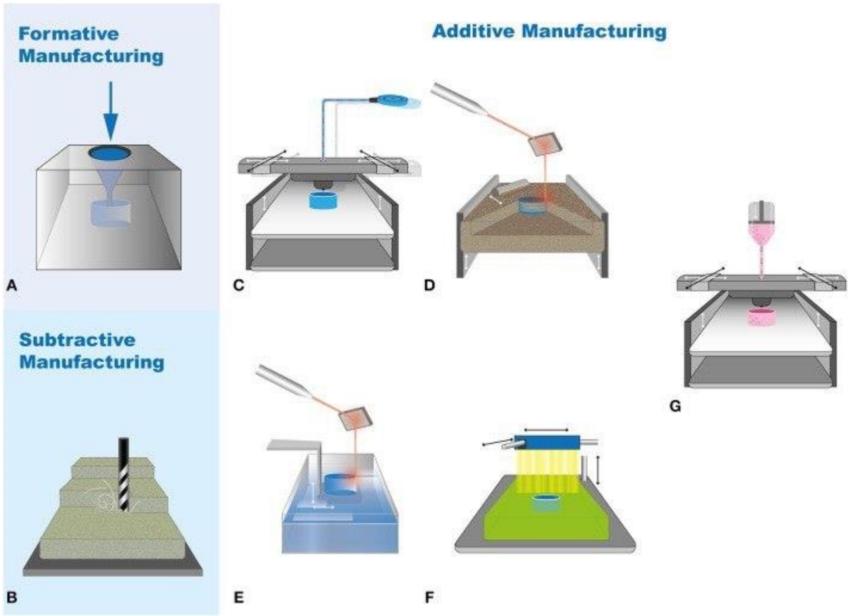

Fig 1.13: Overview on the different manufacturing approaches. Conventional approaches comprising (A) Formative, (B) Subtractive manufacturing; widely applied additive manufacturing methods including (C) Fused deposition modeling (FDM), (D) Selective laser sintering (SLS), (E) Stereolithography (SLA), (F) Polyjet and (G) Bioprinting **(Oberoi et al. 2018)**.

2.3.2 Extraoral scanning: Making a conventional impression that can be scanned with a desktop scanner or poured in gypsum to obtain the master casts that, in turn, are scanned **(Steinmassl et al. 2017)**.

After the initial examination, the first impressions were made with stock trays and irreversible hydrocolloid material and the impressions were sent to a dental laboratory for the fabrication of custom trays and occlusal rims. Occlusal rims and custom trays were made on the same stone casts. The definitive impressions of the maxilla and mandible were made with thermoplastic border moulding material and wash impressions were made with low-viscosity wash material. Following the basic protocol for CDs, the maxillomandibular relationship was recorded. **(Janeva et al. 2017)**.

Fig 1.14: maxillary and mandibular definitive impressions **(Janeva et al. 2017)**.

The midline, smile line, and positions of the canines were marked. The tooth shape and tooth colour were selected, and the order form was completed. **(Janeva et al. 2017)**.

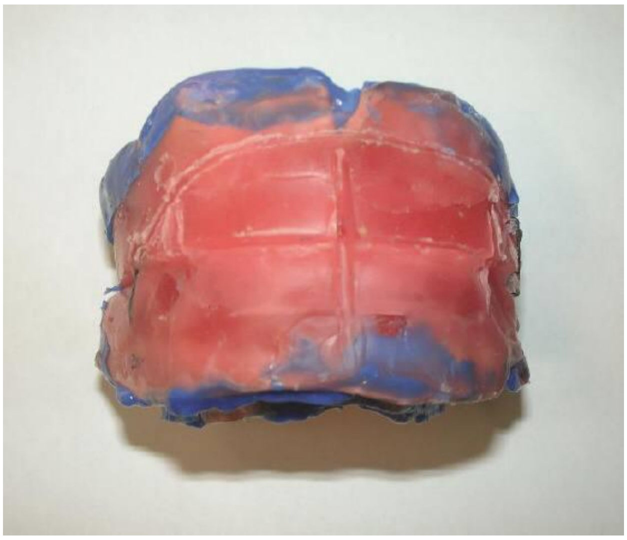

Fig 1.15: occlusal record with wash impression **(Janeva et al. 2017)**.

In the dental laboratory, the maxillary and definitive mandibular impressions and the occlusal rims were prepared for scanning with scan spray. **(Janeva et al. 2017)**.

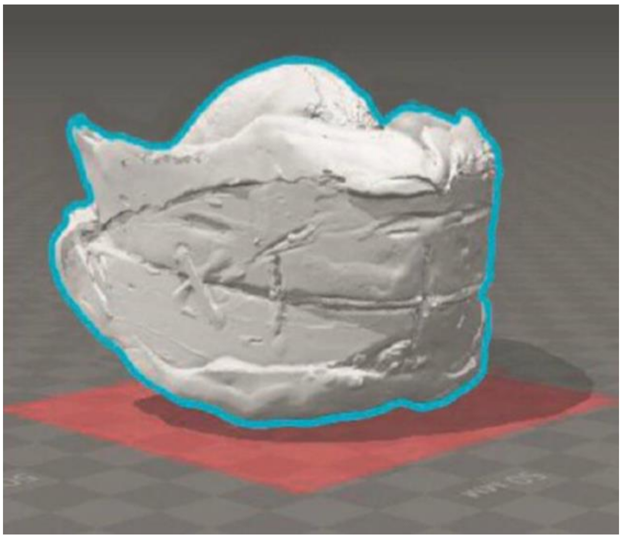

Fig 1.16: STL file: occlusal rims **(Janeva et al. 2017)**.

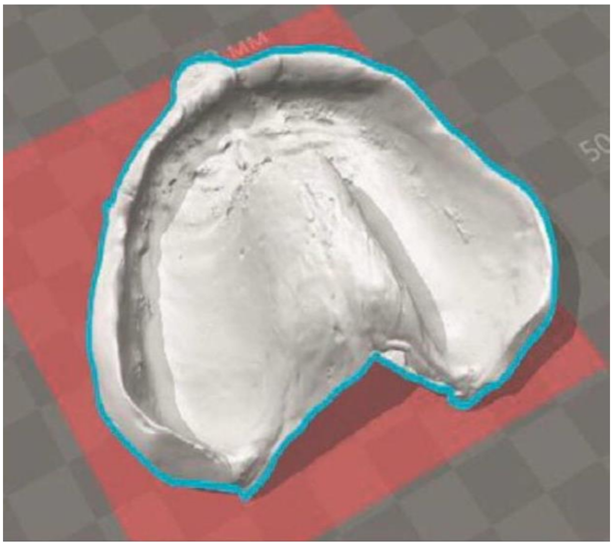

Fig 1.17: STL files: maxillary impression **(Janeva et al. 2017)**.

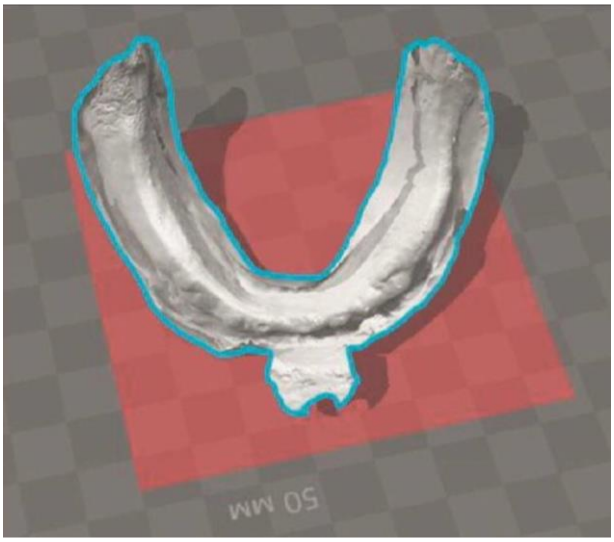

Fig 1.18: STL files: mandibular impression **(Janeva et al. 2017)**.

Scanning was performed with an optical 3D scanner (Open Technologies). The files from the laser-scanned maxillary and definitive mandibular impressions and connected occlusal rims were translated into stereolithography (STL) files and were sent to general dental service (GDS). Once the CDs have been virtually designed in GDS software, a preview is sent for evaluation using 3D viewing software. After minor modifications in the positions of teeth were made, fabrication of the dentures was approved. The digital dentures were fabricated from prepolymerized resin acrylic pucks and were delivered with teeth bonded in the milled recesses. **(Janeva et al. 2017)**.

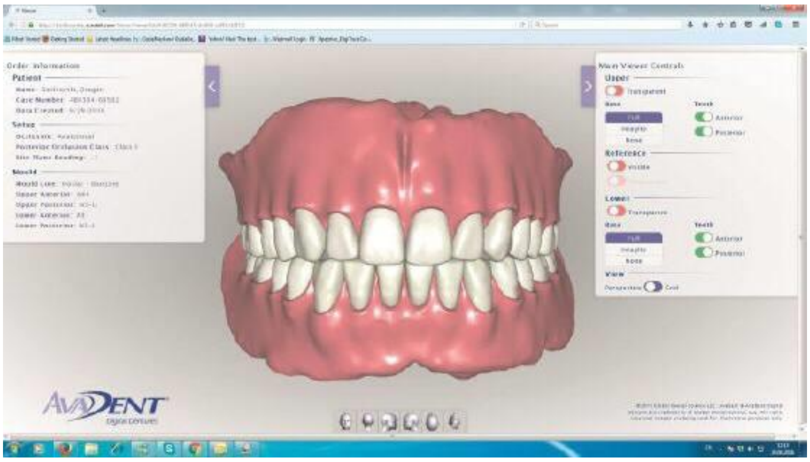

Fig 1.19: preview of virtually designed dentures **(Janeva et al. 2017)**.

After placement, clinical evaluations of the fit, retention, stability, occlusal relationship, esthetics, and phonetics were performed. The digital CDs met the clinical requirements **(Janeva et al. 2017)**.

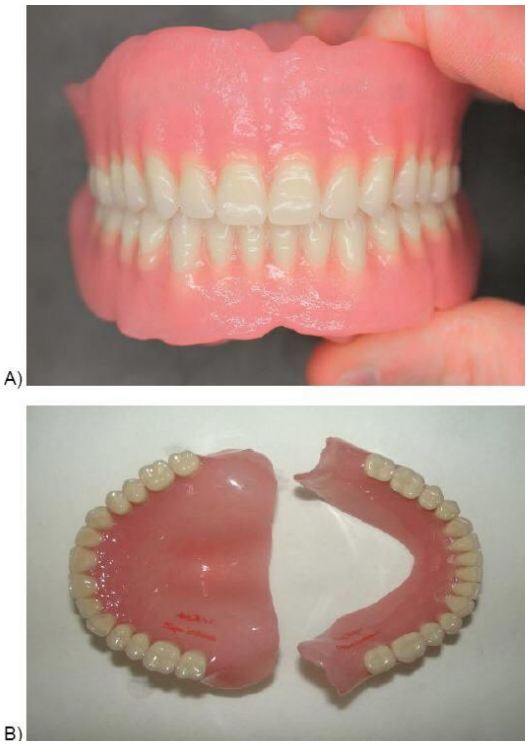

Fig 1.20: A) completed digital dentures b) cameo surface view **(Janeva et al. 2017)**.

2.4 Digital versus conventional impression in complete denture

Digital impressions have several advantages over traditional impressions. They are very beneficial today as a boon to both the dentists and laboratory technicians by enabling them to achieve greater accuracy in any restorative procedures. Shortly, it will be more likely to be a regular dental office procedure, as it benefits dentists, patients, and laboratory technicians. Digital impressions from the patient's perspective save time and is a lot less messy than the traditional technique **(Yuzbasioglu et al. 2014)**.

The difficulty of scanning the distal part in the digital impression and requirement of titanium oxide powder spray for contrast (such as CEREC Bluecam systems) are some disadvantages of the digital system. In addition, the other disadvantages of the digital impression method are cost and requirement of extra education for using. Dental students learn the conventional impression method in the dentistry education. It is also necessary to be informed the students about the technological innovations such as digital impression systems and how to apply them in their professional life **(Ahlholm et al., 2018)**.

2.4.1 Accuracy

According to the International Organization for Standardization (ISO), accuracy is evaluated in terms of **trueness** and **precision**. **Trueness** is defined as the measurement bias or systematic error between the reference object and the target object. **Precision** is defined as the random error (reproducibility) between the objects when the process is repeated. The evaluation of trueness showed that digital impressions obtained using an intraoral scanner with a large scanning head had significantly lower deviation than the conventional impressions. Similarly, the evaluation of precision showed that digital impressions obtained using an intraoral scanner with a small scanning head had significantly higher deviation than the conventional impressions. The results suggested that the accuracy of digital impressions is superior to conventional impressions in terms of trueness, but inferior to conventional impressions in terms of precision, and that accuracy can be improved by increasing the scanning head size **(Malaguti 2016)**.

2.4.2 Time and appointments

Digital impression may reduce the number of clinical appointments required and the chair time and can simplify laboratory procedures. The overall treatment time for the conventional impression technique was longer than that for the digital impression technique. Digital impressions tend to reduce repeat visits and retreatment, while increasing treatment effectiveness **(Beuer et al. 2008)**.

2.4.3 The effectiveness and clinical outcomes

The effectiveness and outcomes of the conventional impression technique was evaluated by measuring the total treatment time, including the individual steps:

a. tray selection

b. adhesive application

c. upper/lower impression

d. Bite registration.

The effectiveness and clinical outcomes of the digital impression technique were evaluated by measuring the total treatment time, including the individual steps:

a. entering patient information (including name, last name, date of birth)

b. laboratory prescription

c. upper/lower scan

d. Bite scan.

The results indicate that the efficiency outcomes of the digital impression technique were higher than that of the conventional impression technique, with respect to treatment time taken up and the perceptions of the subjects **(Eftekhar Ashtiani et al. 2018)**.

2.4.4 Patient preferences

Digital impression was the preferred choice, stated that both the impression techniques were equally acceptable. Preference for digital impression is another indication that today's patients have more concern on comfort. This is because the digital impressions are associated with reduced invasiveness. Unacceptable conventional impressions require remaking of entire impression. However, with digital impression technique missing and unacceptable areas can be corrected by a segmental rescanning. This reduces working time and increases patient comfort **(Gjelvold et al. 2016)**.

2.4.5 Operator's Preferences

The digital impressions were preferred by the operator. Operator centered outcome were measured for digital and conventional impressions by assessing working time, operator perception and procedure difficulty. The workflow of digital impression technique took reduced time. Even though when a remaking was necessary, the time required for rescan of the digital impression was significantly less. Rescans were done mainly due to the difficulty in scanning the interproximal contact areas and in areas of reflection from light source. Operator perception was measured on the level of difficulty in performing the procedure and was significantly lower for the digital impression technique. Manipulation and learning curve for the intraoral scanner were less and they seem to be more user-friendly. Operators perceived that missing and unacceptable area can be corrected more easily with digital impressions while the conventional technique demanded remaking of entire impression **(Lee et al. 2013)**.

2.4.6 Dental students

Students were more familiar with the conventional method before taking the impression. This situation is thought to be due to the fact that the students took conventional impression in the prosthetic courses at the preclinical laboratory while they did not take digital impression. They knew digital impression only as a theoretical course. Students found the digital method easier than conventional method in the study of Lee and Gallucci in 2013 **(Lee et al. 2013)**.

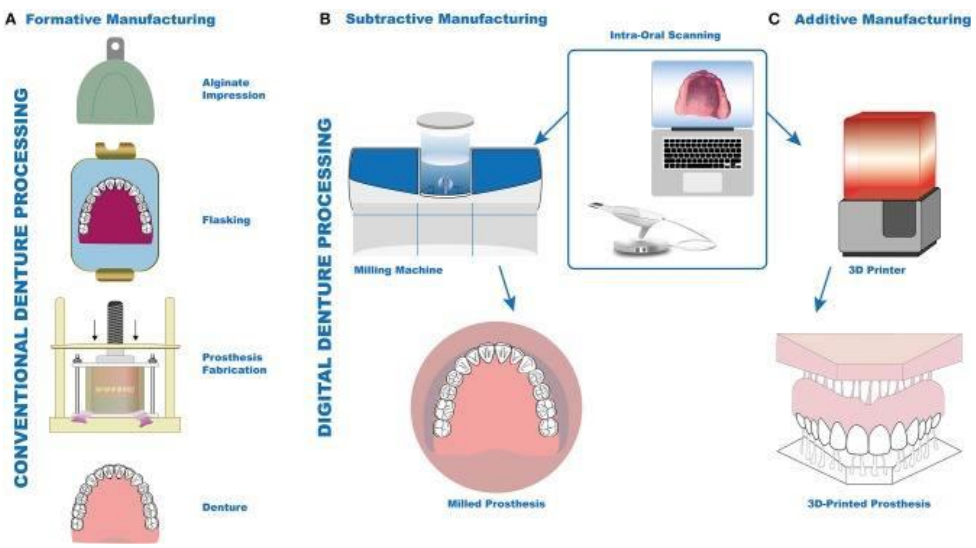

Fig 1.21: Conventional and digital prosthesis fabrication approaches. Conventional approach for denture fabrication by alginate impression and flasking method (A, Formative manufacturing). Digital approach with intra-oral scanning-based impression; manufacturing of denture either by CAD/CAM (B, subtractive manufacturing) or 3D printer (C, additive manufacturing) **(Oberoi et al. 2018)**.

2.5 Advantages of CAD/CAM complete denture: (Baba et al. 2015).

1. Reduction in the number of patient's visits could be advantages for old patients who have hard time travelling back and forth to the dental office.

2. Reduction in the clinical chair time for the fabrication of complete dentures, decreases the clinician's overhead.

3. All collected data, produced images and tooth arrangements can be saved digitally and used for future fabrication of an additional denture, lost denture or a surgical/ radiographic template.

4. Time-consuming laboratory procedures are reduced or eliminated. allowing the dental technician to ensure reproducible, efficient and accurate prosthesis.

5. The prepolymerized acrylic resin used by some manufactures for the fabrication of the denture base provides a superior fit and strength when compared to conventionally processed bases. The milled prepolymerized acrylic resin undergoes no polymerized shrinkage.

6. Independent researches indicates that preoplymerized acrylic resin (PAR) Contains less residual monomer and is more hydrophobic than the conventionally processed acrylic resin. PAR reduces the potential for infections because less microorganisms (i.e., C.albicans) attaches to denture bases.

2.6 Disadvantages of CAD/CAM complete dentures

1. Balanced dentures are difficult to achieve with the dental software used for the digital design of the complete dentures requiring a clinical remount to balance the denture teeth **(Baba et al. 2015).**

2. Skipping the trial denture appointment can deprived the clinician opportunity to evaluate esthetics, and phonetics and perform any needed adjustments **(Baba et al. 2015)**.

3. Expensive materials, and increased laboratory cost compared with those for conventional methods **(Bilgin et al. 2016)**.

4. Other major problem is the potential for the dental team to resist the system's use and the clinician's lack of confidence in using a computerized system **(MIYAZAKI et al. 2009)**.

Chapter two

Discussion

Compared with the conventional technique for fabricating CDs, the digital workflow has several advantages. Besides a reduction in the number of visits and reduced clinical chair time, the repository of digital data in the manufacturer (GDS) database allows for the rapid future fabrication of spare or replacement dentures **(Janeva et al. 2017)**.

Since the dentures are milled from a prepolymerized acrylic resin puck, which is produced under high pressure and heat, polymerisation shrinkage does not occur, porosity is decreased, and the adherence of Candida albicans to the denture base is decreased. The lack of polymerisation shrinkage associated with milled dentures results in a highly accurate denture fit and improved retention **(Goodacre et al. 2016)**.

The lack of clinical trial placement procedures might be a disadvantage of using CAD/CAM dentures. The definitive impressions and the maxillomandibular relation can be obtained using different techniques. According to Schwindling et al., improvements leading to the recording of the maxillomandibular relation using manual methods might increase the attractiveness of digital CD systems **(Schwaindling et al. 2016)**.

When sending data to the manufacturer for designing and milling, an accurate maxillomandibular record, acceptable definitive impressions, and satisfactory overall records result in an outcome with favourable properties **(Janeva et al. 2017)**.

Patients more prefer the digital method because it is less invasive and saving them discomfort.

Students found the digital method easier than conventional method in the study of Lee and Gallucci in 2013 **(Lee et al. 2013)**.

Chapter three

Conclusion and Suggestions

In the light of this information:

1. CAD/CAM technology has become a core part of dentistry.
2. CAD/CAM in different dental specializations has created new opportunities for providing high-quality dental care, at the same time the integration of cad / cam in dentistry help improve the quality of the restoration and reduce the working time.
3. Digital denture technology has simplified the designing and manufacturing process for complete dentures, and produces better-adapted prostheses with superior material properties.
4. In addition, the data can be reserved for long time. It is very useful in the case if the patients lost their dentures or if we need to refabricate the dentures so we will benefit from the reserved data without the need for retaking the impression.
5. A significant disadvantages of digitally fabricated dentures is that clinicians and patients lack the opportunity to evaluate a trial denture intraorally.
6. It also must be mentioned that the patient satisfaction and convenience will be enhanced by the enhancing of the quality of instrument and devices used.

However, the final results depend on the skills and knowledge of dental team.

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