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Digital Dentistry for Complete Denture

A Project Submitted to
The College of Dentistry, University of Mosul, Department of Prosthodontics in Partial Fulfillment for the Bachelor of Dental Surgery

By

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Certification of the Supervisor

I certify that this project entitled (**Digital dentistry for complete denture**) has been prepared **by Marwa Ahmed Ghanim** under my supervision at the Department of Prosthetic Dentistry, College of Dentistry, University of Mosul in partial fulfillment of the graduation requirements for the Bachelor Degree in Dentistry.

Dr. Ali Salah Alshammari

Lecturer /

Dedication

Marwa

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List of Abbreviations

Abbreviation	Full text
CAD	Computer aided designing
CAE	Computer aided engineering
CAM	Computer aided manufacturing
CBCT	Cone beam computer tomography
CNC	Computer numerical control
LED	Light emitting diode
MMA	Methyl-methacrylate
OVD	Occlusal vertical dimension
PMMA	Poly methyl-methacrylate
RP	Rapid prototyping
STL	Standard transformation language

Introduction

Introduction

Although dentists may offer an edentulous patient in the first place an implant therapy, there are reasons to refuse this type of treatment by the patient: anxiety about surgery, fear of pain, costs, and treatment time. Furthermore, from a general health point of view, patients may not be candidates per se for implants: uncontrolled diabetes, immune deficiency issues, heavy smoking habits, alcohol abuse, psychology, and dementia **(Kullar and Miller, 2019)**.

In such cases, professionally fabricated and well-maintained removable complete dentures still represent a treatment of choice. Fabrication of conventional complete dentures involves a complex restoration method, requiring significant time and typically involving primary impressions, definitive impressions, jaw relation records, clinical try-in, and complete denture placement **(Basker et al., 2011)**, which has been used for nearly a century without change. However, inexperienced dentists or students often face difficulty with achieving satisfactory retention, stabilization, and balanced occlusion of complete dentures, especially in some elderly patients and those with severe alveolar ridge absorption. In recent years, digital complete denture systems have been developed that can improve the accuracy and efficiency of denture fabrication and reduce the required number of clinic visits. These systems involve different protocols for clinical and laboratory processes, requiring two to five clinical visits **(Bidra et al., 2013; Schweiger et al., 2018)**.

The CAD/CAM process in Dentistry describes an indirect restoration designed by a computer (Computer Aided Design) and milled by a computer-assisted machine (Computer Aided Machined) **(Correia et al., 2006)**. Despite the exceedingly growing use of dental implants, dentures still represent an indispensable treatment option for some edentulous individuals who cannot afford or are contraindicated for implant therapy. Over the past 100 years, complete denture fabrication has not changed considerably and was mainly based on conventional techniques which consists of multiple steps requiring traditionally 4 to 5 clinical appointments, from the preliminary impressions to denture placement, and lengthy laboratory procedures. This usually requires substantial human intervention and extensive material manipulation, which may lead to inaccuracies, processing errors, and increased time and expenses **(Bidra et al., 2013)**.

For several years now, computer-aided design and computer-aided manufacturing (CAD/CAM) technology has been available and continues to develop in the field of fixed prosthodontics showing significant impact on the design and fabrication of fixed dental prostheses **(Miyazaki et al., 2009)**. Recently however, it has expanded to embrace implant, maxillofacial and removable prosthodontics including the fabrication of complete dentures ***(Busch and Kordass, 2006)***.

Aims of the study

The aim of the review is to present the historical, clinical, and technological developments in the field of digital removable complete dentures.

Chapter One:
Review Of Literature

Chapter One: Review Of Literature

1.1 Epidemiology of Edentulism and Longevity of Complete Dentures.

Edentulism is the state of being edentulous, or without natural teeth **(Adam, 2006)**. Complete edentulism is an oral cavity without any teeth. Adequate dentition is quite essential for well-being and life quality. Edentulism is one of the public health burdens for elderly people and effects clearly affects the practice of primary care. Edentulism is a devastating and irreversible condition and is described as the "final marker of disease burden for oral health. Patients who are suffering from edentulism exhibit a wide range of physical variations and health conditions. Teeth loss affects mastication, speech, and may result in poor esthetics which in turn affect the quality of life **(Cunha-Cruz et al., 2007)**.

Evidence regarding the longevity of complete dentures is limited. A recent systematic review found a denture replacement period of about 10 years, in which the longevity of maxillary dentures was greater than that of mandibular dentures. The authors claim to educate patients to seek regular maintenance for their dentures as well as for their oral mucosal health **(Taylor et al., 2021)**.

1.2 Digital Complete Denture

1.2.1 Definition and History

According to the Glossary of Digital Terms, a digital denture is a complete denture created by or through automation using CAD (computer-aided designing), CAM (computer-aided manufacturing), and CAE (computer-aided engineering) in lieu of traditional processes. A digital denture is achieved when the final shape of the denture is manufactured through automation to ensure there are no conventional errors from pouring, investment casting, or injecting the material as done in traditional denture fabrication **(Grant et al., 2016)**.

CADCAM has become an indispensable part of dentistry in general and of prosthodontics in particular. The idea of successfully digitizing the workflow for fabrication of complete dentures was considered for a long time as rather improbable. It was felt that the necessary comprehensive application of individual clinical and technical rules, as well as of the essential clinical experiences of dentist and dental technologist, may be obstacles. Although the conventional workflow to fabricate complete dentures is well established and successful, factors such as standardization and simplification accelerated the interest in CAD-CAM technology for removable prosthodontics **(Bidra et al., 2013).**

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)**. Earlier CAD/CAM innovations were mostly geared toward indirect, tooth-borne restorations. The first report of CAD/CAM use for dentures is attributed to **(Maeda et al., 1994)**, who, in 1994, employed additive manufacturing technology. In The 1990S, Fabricated A Complete Denture for The First Time by Using Computer-Aided Design/Computer-Aided Manufacturing (Cad/Cam) Technology **(Maeda et al., 1994)**.

1.2.2 CAD/CAM systems parts

1.2.2.1 A data acquisition unit

Which gathers the information or data from the mouth and then converted into visual or optical impressions which are created directly or indirectly at the same time **(Deng et al., 2020)**.

1.2.2.2 Prosthesis design

Denture-designing software offers a powerful tool that lets clinicians select molds from a library of teeth to generate the tooth arrangement automatically although it is still possible to customize the tooth setup. It is the authors' opinion that use of CAD technology for complete dentures can be a great teaching tool for students, as it can show them the proper positioning of the denture teeth in terms of esthetics, relationship to the residual ridge, location of the occlusal plane, and occlusal relationship **(Deng et al., 2020)**.

1.2.2.3 Manufacturing Technologies

Since the introduction of polymethyl methacrylate by Wright in 1936, many issues of conventional complete denture materials have been associated with polymerization shrinkage, leading to issues of fit, strength, and also release of monomer. With CAD/CAM technology, two types of fabrication methods can be used to overcome these shortcomings **(Deng et al., 2020)**.

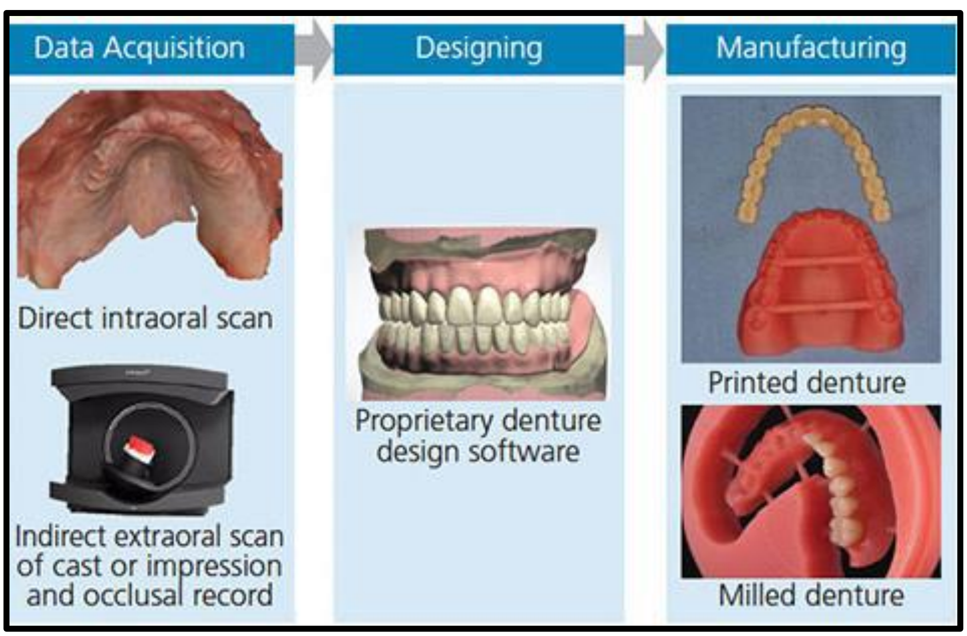

Figure 1 Computer aided design/computer aided manufacturing workflow (Deng et al., 2020).

1.3 Stages in fabrication of prosthesis with CAD/CAM technology

1.3.1 Computer surface digitization

Scanning of prepared tooth is done either digital (with Light emitting diode LED based or Laser based) or mechanical scanners **(Patil et al., 2018)**.

1.3.1.1 Digital (either LED or laser based)

1.3.1.1.1 Based scanner.

A small hand-held video camera with a 1cm wide lens (scanner) when placed over the occlusal surface of the prepared tooth, emits infrared light which passes through an internal grid containing a series of parallel lines. The pattern of light and dark stripes which falls on the prepared tooth surface is reflected to the scanning head and onto a photoreceptor, where its intensity is recorded as a measure of voltage and transmitted as digital data to the CAD unit **(Patil et al., 2018)**.

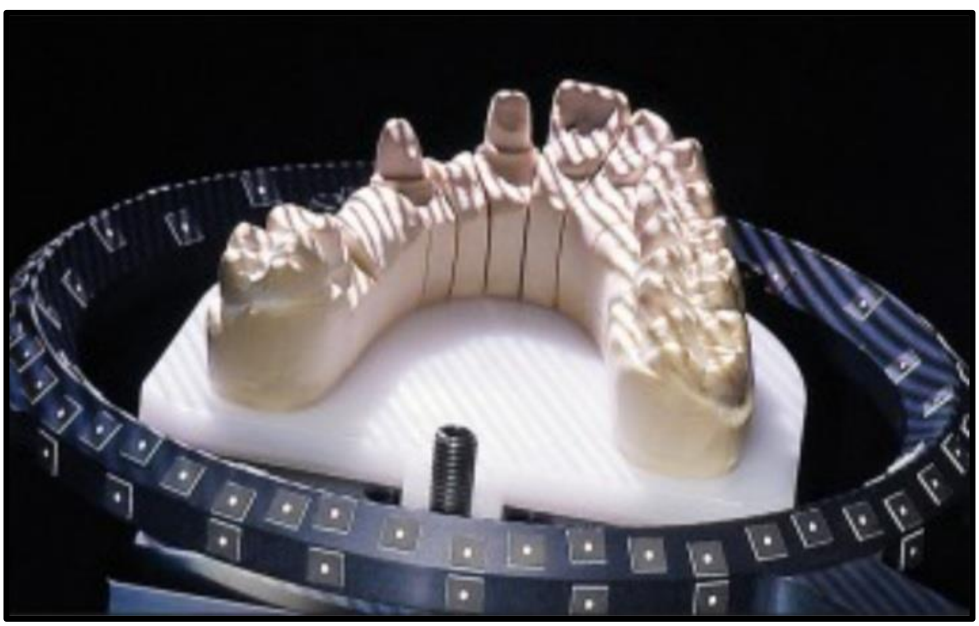

Figure 2 LED Based scanner

1.3.1.1.2 Laser based scanner

A high-speed laser takes digital scans of the preparation and proximal teeth to create an interactive 3D image. Rapid scan allows automatic capture of digital images at the operator's preferred speed to scan in the mouth or extra-orally on conventional impressions or models, all without powder. Newer laser-based scanners can scan at subgingival level based on optical coherence (OCT). At least 9 scans are required to produce the image. There are stabilizers present with the scanning device **(Patil et al., 2018)**.

Figure 3 Laser Based scanner.

Figure 4 A-intra oral

Figure 5 extra oral scanners

1.3.1.2 Mechanical scanner

In this scanner variant, the master cast is read mechanically line-by-line by means of a ruby ball and the three-dimensional structure measured. The Procera Scanner from Nobel Biocare (Göteborg) is the only example of mechanical scanners in dentistry. This type of scanner is distinguished by a high scanning accuracy, whereby the diameter of the ruby ball is set to the smallest grinder in the milling system, with the result that all data collected by the system can also be milled. The drawbacks of this data measurement technique are to be seen in the inordinately complicated mechanics, which make the apparatus very expensive with long processing times compared to optical **(Webber et al., 2003)**.

1.3.2 Computer- aided designing

It is a computer unit with a software package for visualization of the scanned data, planning and designing dental restorations on a computer screen. Software's collect data in the "Standard Transformation Language (STL)" or so called

"Standard Tessellation Language" format. It is possible to design a variety of dental restorations such as veneers, inlays, onlays, individual crowns, bridge copings, partial denture frameworks and complete dentures. When the design of the restoration is complete, the CAD software transforms the virtual model into a specific set of commands, which in turn drive the CAM unit to fabricate the designed restoration (Beuer et al., 2008; Bilkhair, 2013).

The software of the CAD-CAM systems can be divided into two types based on the digital data sharing capacity: closed and open systems. In the closed system, all the steps of digitizing, designing and manufacturing are integrated in the unique system with no interchangeability with any components manufactured by another company. e.g., CEREC® AC-Bluecam, Apollo DI and CEREC® AC-Omnicam (Sirona Dental System). However, the new trends are directed towards the open systems, which allow the adoption of the original digital data by CAD software and CAM devices from different companies (Ting-Shu and Jian, 2015; Alghazzawi, 2016).

1.3.3 Computer-aided manufacturing (CAM)

Third and the final stage is computer-aided manufacturing (CAM). The CAM technologies can be divided in three groups according to the technique used (Parasher, 2014):

1.3.3.1 Subtractive technique from a solid block

In this stage the milling is done with computerized electrically driven diamond disks or burs which cut the restoration from ingots or blocks. The CAM

1.3.3.2 Additive technique (Solid free form fabrication):

This category of new technologies originating from the area of rapid prototyping (RP), The term 3-D printing is generally used to describe a manufacturing approach that builds objects one layer at a time, adding multiple layers to form an object. This process is more correctly described as additive manufacturing and is also referred to as rapid prototyping which have been adapted to the needs of dental technology (Prajapati et al., 2014).

1.3.3.3 Additive technique (by applying material on die)

Here in this technique Alumina or Zirconia is dry pressed on the die and the temperature is raised to a temperature similar to the pre sintering state. At this stage, enlarged and porous coping is stable. Its outer surface is milled to the desired shape and coping, removed from die, and sintered into the furnace for firing to full sintering (Tamrakar et al., 2014).

1.4 Classification of CAD-CAM systems

The CAD-CAM system classified according to production method into:

1.4.1 Subtractive method (milling method)

The prepolymerized acrylic resin used to fabricate milled CAD-CAM complete dentures is dimensionally stable and provides a superior fit of the denture bases whereas the resin of conventional processed bases undergoes polymerization shrinkage (AlHelal et al., 2017; Goodacre et al., 2018).

The prepolymerized acrylic resin has improved physical properties allowing for designing a thinner base overlying the palate. This property is particularly advantageous when an immediate denture will overlay a prominent anterior maxilla. A thinner facial flange is associated with less prominence of the upper lip and a more esthetic result. There is evidence of improved physical properties of the milled base material. For instance, the resin is more hydrophilic (wettable) (Sipahi et al., 2001), contains less residual monomer (Ayman, 2017; Steinmassl et al., 2017), has a smoother surface (Arslan et al., 2018; Srinivasan et al., 2018), provides better resistance to surface staining (Al-Qarni et al., 2020), and exhibits a higher modulus of elasticity (Steinmassl et al., 2017), flexural strength (Arslan et al., 2018; Al-Dwairi et al., 2020), and fracture toughness (Steinmassl et al., 2017). In addition to containing less residual monomer, the milled prepolymerized acrylic resin is denser than heat-activated conventional denture base resins (Ali et al., 2008; Ayman, 2017).

1.4.1.1 A Review of subtractive method

Subtractive manufacturing was used by (Kanazawa et al., 2011). in an effort to improve and speed up the CAD-CAM denture fabrication process. They scanned a set of artificial teeth and the patient's existing complete denture and used a cone beam computed tomography scan (CBCT) to obtain information about the patient's mucosa and centric relation. The virtual denture was designed with the use of a 3D-CAD software program. Then a subtractive milling machine computer numerical control (CNC) was employed to mill the transparent denture bases with recesses into which denture teeth were subsequently bonded manually. CAD-CAM systems offer numerous clinical benefits since the PMMA pucks used for the milling of denture are polymerized by injection under high temperature and pressure, a process that promotes the formation of longer polymer chains leading to a higher degree of monomer conversion and lower values of residual monomer as well as minimal porosity. It is probably a result of the processing method under high temperature –

pressure leading to a low residual MMA concentration (Murakami et al., 2013; Kattadiyil et al., 2015).

It has been reported that these processing conditions decrease the intermolecular distances and reduce the free volume (Ali et al., 2008).

Surface hardness indicates the density of the material and its resistance to wear and-or scratching which reflects on the dental prosthesis during its function and cleaning (Murakami et al., 2013).

The results of the present study showed a significant attributed to the polymerization process of each resin as the heat cure is polymerized by additional (free radical) polymerization and leads to the formation of a partial cross-linked polymer chain which results in the superior hardness. On the other hand, the high temperature and high-pressure conditions for the polymerization of CAD-CAM resins and the addition of inorganic fillers restrict dimensional polymerization shrinkage and enhance the CAD-CAM resins mechanical properties including hardness and wear resistance (Ali et al., 2008; Consani et al., 2014).

With the subtractive method, the denture base is milled from a pre polymerized resin blank. Depending on the system, prefabricated or milled denture teeth are subsequently bonded on the base. Such contemporary systems include Zirkonzahn Denture System (Zirkonzahn, Italy), Ivoclar Digital Denture (Ivoclar Vivadent, Liechtenstein), Vita Vionic (Vita Zahnfabrik, Germany) and AvaDent Digital Dentures Bonded Teeth (AvaDent, USA). Recently, few systems developed a method to mill the denture and the teeth out of a single blank AvaDent Digital Dentures XCL1 and XCL-2, Baltic Denture System (Merz Dental, Germany) and Ivoclar Vivadent Ivotion (Anadioti et al., 2020)

The main disadvantage of the subtractive technique is the waste, as a large

portion of the blank remains unused and is discarded during this process. Another limitation is the monochromatic and unaesthetic teeth, which AvaDent has overcome in their XCL-2 denture by using a unique layering system resulting in polychromatic teeth that simulate the dentin and enamel of natural teeth, providing premium esthetics (Lamb et al., 1983).

1.4.2 Additive method (rapid prototype)

Additive manufacturing is an alternative to the traditional product manufacturing process through which three-dimensional (3-D) solid objects are created. It enables the creation of physical 3-D models of objects using a series of additive or layered development frameworks, where layers are laid down in succession to create a complete 3-D object, in other words, additive manufacturing is the same as 3-D printing (Lindemann and Jahnke, 2017).

Additive manufacturing consumes less material and produces the fine details, undercuts, and voids that are difficult to reproduce with subtractive manufacturing. (Lindemann and Jahnke, 2017).

1.5 Applications of Digital Dentures

1.5.1 Fabrication of immediate dentures:

The digital protocol can be applied to the fabrication of immediate dentures. The steps involve making digital/conventional impressions, conventionally registering the interocclusal records, assessing the position of the existing natural teeth in the mouth, and recording the changes required to be made to the existing tooth positions. All the records are sent to the laboratory where they are scanned for digital denture fabrication. The teeth are virtually extracted from the virtual casts and prosthetic teeth are planned in optimal locations based on the clinical records. A try-in prosthesis may be printed for the try-in procedure if needed. The digital dentures are milled or printed, natural teeth are extracted and the digital dentures are placed in the oral cavity using conventional prosthodontic procedures. (Tamrakar et al 2021)

1.5.2 Fabrication of radiographic guide:

Radiographic markers can be attached to the digital prostheses or the prototype dentures and then they can be used as a radiographic guide while recording a cone beam computerized tomography (CBCT) scan. The data obtained from the CBCT scan can be used to plan implant positions and also fabricate a surgical guide which will help with the 3D placement of the implants. The data generated during the fabrication of the prototype can then be used as a guide for framework fabrication and milling of the definitive prostheses. (Srinivasan et al 2019)

1.5.3 Fabrication of implant-supported overdentures:

The protocol used for the fabrication of complete dentures can also be used to fabricate an implant-supported overdenture. However, there are a few minor variations, they include the following:

- The attachments are selected based on the height of the mucosal cuff and are attached to the implants.
- A processing spacer is placed over the attachments.
- Conventional/digital impressions and records are made with the attachments and the processing spacer in the mouth.
- All the records are sent to the laboratory and scanned for digital denture fabrication. Recesses are planned in the denture base in the location of the overdenture attachments and the retentive elements of the attachments are picked up chairside at the time of prosthesis placement.

1.5.4 Fabrication of implant-supported fixed prostheses:

The data generated during the fabrication of the prototype/transitional denture can be used as a guide for framework fabrication and milling of the definitive fixed prosthesis as the same tooth positions are used throughout the treatment.

1.6 Limitations of Digital Dentures

1. Adjustments and relines associated with IOS use: When the IOS is used to record the denture-bearing tissues, relines and repeated adjustments of the intaglio surface and borders are needed to achieve an optimal fit of the digital prostheses. (Srinivasan et al 2018)
2. Suboptimal esthetics due to elimination of try-in: Several digital protocols advocate the elimination of try-in procedures to save time and cost as they permit virtual evaluation of patient esthetics. However, the prostheses may not have the desired result when placed in the patient's mouth thereby resulting in patient dissatisfaction and treatment failure. (Bidra et al 2013)
3. Learning curve: Fabrication of digital complete dental prostheses requires specialized clinical training and there is a learning curve attached to it. To achieve a successful outcome, the dental practitioner needs to invest time and effort in assessing digital previews and should also actively participate in electronic communication with the laboratory. (Bidra et al 2013)
4. Impossible to digitally register the interocclusal records: It is currently impossible to digitally register the interocclusal records (for patients without existing dentures) and challenging to record digital functional impressions, thus the full digital workflow for the complete denture rehabilitation remains questionable. (Bidra et al 2013)

5. Inability to balance digital dentures: It is not possible to balance digital dentures during the designing phase of denture fabrication

1.7 Advantages for the Dentist, Dental Technologist, and Patient

1. Fewer clinical visits: The fabrication of digital complete dental prostheses requires a fewer number of clinical steps compared to conventional complete dentures; It is possible to record all the clinical information in one appointment and place the CAD-CAM dentures at the next appointment. (Kullar et al 2019)
2. Simplified and reduced laboratory steps: The laboratory procedures are greatly reduced and simplified as the arduous task of teeth setting and denture processing are accomplished with CAD-CAM technology. (Kullar et al 2019)
1. Superior retention and fit: Digital complete dentures are reported to have superior retention and fit compared to conventional complete dentures due to minimal fabrication distortion. .(Schweigera ET AL 2018)
3. Lower incidence of sore spots: As the digital dentures are milled from a prepolymerized block of acrylic resin, there is reduced polymerization shrinkage and a lower incidence of sore spots and microbial colonization.16
4. Superior physical and mechanical properties: Digital complete dentures are reported to have superior physical and mechanical properties compared to conventional complete dental prostheses thereby permitting the fabrication of digital denture bases with a reduced thickness. (Busch and Kordass 2006)
5. Minimal denture tooth movement: Digital fabrication results in minimal denture tooth movement thereby decreasing the need for repeated occlusal adjustments. (Busch and Kordass 2006)

6. Try-in: Digital technology can be used to print a trial prosthesis that can be used to evaluate the aesthetic and function prior to its finalization. (Basker et al 2011)
7. Rapid fabrication of a spare/new prosthesis: Fabrication of digital prostheses helps generate a repository of digital data which enables rapid fabrication of a spare or new prosthesis, without any clinical appointments. (Kullar et al 2019) This reproducibility is particularly helpful for patients who are medically debilitated and cannot visit the dental office. The new replacement denture will have the exact form as the previous denture thereby facilitating quick patient adaptation.
8. Cost: The cost of a digital complete dental prosthesis eventually turns out to be less than the cost of a conventional acrylic complete dental prosthesis as the number of clinical appointments and laboratory procedures are significantly reduced. (Busch and Kordass 2006)
9. Standardization and quality control: Digital dentures may permit improved standardization in clinical research and quality control on complete dentures as well as implant-retained overdentures. (Busch and Kordass 2006)

9.1 Disadvantages of CAD-CAM complete dentures

2. Specialized clinical training required: Fabrication of digital complete dental prostheses requires specialized clinical training and there is a learning curve attached to it. (Correia et al 2006)
3. Time: Dental practitioners need to invest considerable time in the planning, laboratory communication, and execution of digital complete dental prostheses. However, experience with this new technology may help speed up these procedures. (Correia et al 2006)

4. Compromised esthetics: When the try-in procedure is eliminated, it precludes the assessment of the esthetics, phonetics, and occlusion prior to the fabrication of the definitive prostheses. This may result in patient dissatisfaction and failure of the treatment rendered. (Kullar et al 2019)
5. Bond between the artificial teeth and the denture base: There is a concern regarding the bond between the artificial teeth and the prepolymerized denture base being sub-optimal. (Miyazaki ET AL 2009) Milling/printing the denture as a single unit (along with the artificial teeth) helps circumvent this problem.(Schweigera ET AL 2018)

Chapter two:
Discussion and Comment

Chapter Two: Discussion And Comment

Conventional full-arch impression exhibited higher accuracy compared to direct intra oral scanner and the conventional impression would require more experience to achieve the same level of proficiency as digital impression. Digital impressions offer speed, efficiency, ability of storing captured information indefinitely and transferring digital images between the dental office and the laboratory. The advantages of the digital impressions and scanning systems are improving patient acceptance, reducing the distortion of impression materials, 3D pre-visualization of tooth preparations, and potential cost- and time effectiveness. The treatment comfort of the digital impression technique was higher than that of the conventional impression technique when it was performed by an experienced dentist. Digital denture technology has simplified the designing and manufacturing Process for complete dentures and produces better-adapted prostheses with superior material properties.

Chapter Three:
Conclusions and Suggestions

Chapter Three: Conclusions And Suggestions

3.1 Conclusion

It is now possible to fabricate a complete denture with CAD/CAM technology. This fabrication has positive benefits for both the patient and the practitioner. However, the result depends on the skill and knowledge of materials, anatomy, occlusion, function, making accurate impressions, registering the inter-occlusal record with a special device and determining the proper esthetic parameters.

3.2 Suggestion

- Compare the impression clinically.
- Increase the number of surveyed dentists and involve the patient in it.
- Long term evaluation of the final prosthesis for each type of impression technique.

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