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Digital complete denture construction: Clinical and laboratory aspects

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

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

﴿وَلَمَّا بَلَغَ أَشُدَّهُ وَاسْتَوَى آتَيْنَاهُ حُكْماً وَعِلْماً

وَكَذَلِكَ نَجْزِي الْمُحْسِنِينَ﴾

صَدَقَ اللهُ العَظِيمُ

القصص ١٤

Certification of the Supervisor

I certify that this project entitled "Digital complete denture construction: clinical and laboratory aspects " was prepared by the fifth-year student (Marwa kareem Jabbar) under my supervision at the College of Dentistry/University of Baghdad in partial fulfilment of the graduation requirements for the bachelor's degree in Dentistry.

Signature

Assist. Lec. Ban Saad Jassim

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Supervisor

DEDICATION

As well as everything that I do, I would be honor to dedicate this Compilation to my parents. The two person that gave the tools and values necessary to be where I am standing today.

My rock, mom, I want to express my deepest gratitude for your unconditional love and care. I will always know what it's like to be loved and protected because of you.

My hero, dad, I was never afraid to go off on my own because I knew you would be there anytime I needed you.You are my role model in the life, I appreciate you for allowing me to be like you.

My lovely persons (sister, brother, friends), I always feel special because of you.Thank you for making the time to listen, give advice with loving intentions and always support me. Grateful to have you.

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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

Although dentists may offer to 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 has 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).**

AIM OF 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 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 Challenges of Treatment with Complete Dentures

The conventional workflow for fabrication of complete dentures is elaborate and requires considerable time and experience in the clinic and especially in the dental laboratory. It normally takes 4–5 sessions:

(i)a primary impression with a prefabricated impression tray or with the existing denture,

(ii) a final impression with a customized impression tray,

(iii)a determination of the vertical and horizontal dimension,

(iv) a functional and esthetic try-in of the denture teeth, and

(v) a delivery and incorporation of the complete dentures.

Furthermore, the post-insertion workload for maintenance and repair of the dentures must be considered **(Felton *et al*., 2011).** These sessions are accompanied by a subtle and laborious handicraft in the laboratory. A simplification of the treatment is desirable by combining some clinical and laboratory steps and by saving time and possibly costs for dentist, technologist, and patient. Systematic reviews confirm that a conventional step-by-step complete denture fabrication procedure does not produce perse better clinical results than the use of a simplified method in terms of general satisfaction, denture quality, and mastication ability. The often reduced neuroplasticity and stereognostic abilities of elderly edentulous patients may provoke adaptation problems to new complete dentures. In such cases, digitally fabricated duplicate new dentures may be an adequate and efficient solution **(Takeda *et al*., 2020)**. They allow the processing of a high-quality biomaterial and a better adaptation of the intaglio fit, while copying the functional areas of the cameo surface of the existing dentures. Furthermore, the digital data of the denture in case of loss, fracture, or reworking remain available to replicate the affected dentures. This may be particularly important for the frail elderly in longterm care facilities. In such cases, additionally the potential microbiological burden (e.g., risk for aspiration pneumonia, adherence of candida) from the removable dentures must be considered. From a biological point of view, easy cleansable complete dentures with a high-quality surface (no porosities, easy polishable) facilitating denture hygiene -could potentially have a relevant preventive effect on mortality from pneumonia in hospitalized elderly people and elderly nursing home residents **(Al-Fouzan *et al*., 2017).**

1.3 Digital Complete Denture

1.3.1 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). CAD-CAM 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 was 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).**

1.3.2 CAD/CAM systems parts

(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).**

(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).**

(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).**

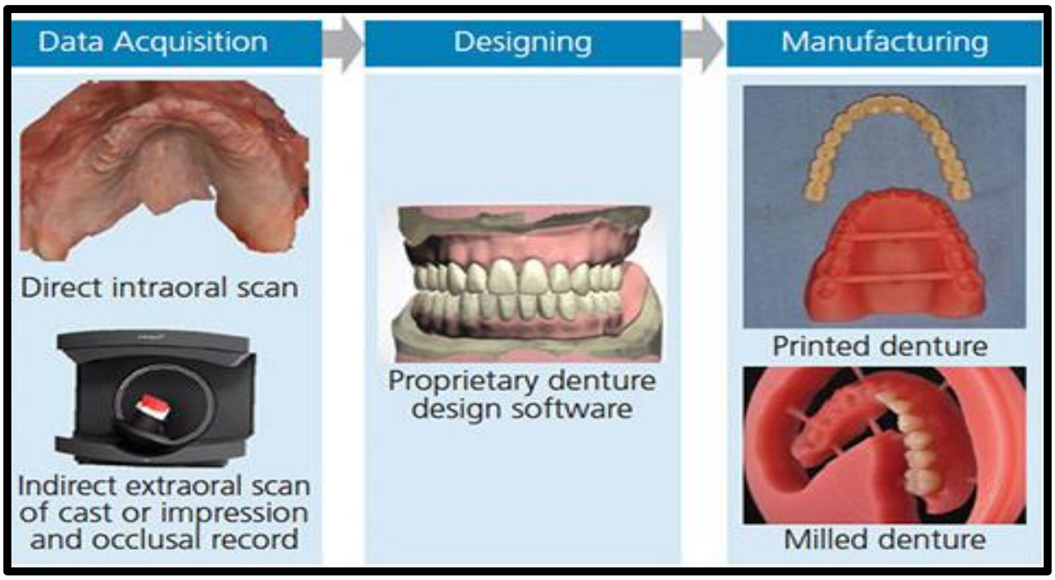

Figure 1.1: Computer aided design/computer aided manufacturing workflow **(Deng *et al*., 2020).**

1.4 Stages in fabrication of prosthesis with CAD/CAM technology

1. Computer surface digitization
2. Computer-aided designing
3. Computer-aided manufacturing
4. Computer-aided esthetics
5. Computer-aided finishing

The last two stages are more complex and are still being developed for inclusion in commercial system **(Patil *et al*., 2018).**

1.4.1 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).**

1.4.1.A Digital (either LED or laser based)

I. LED 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 back 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).**

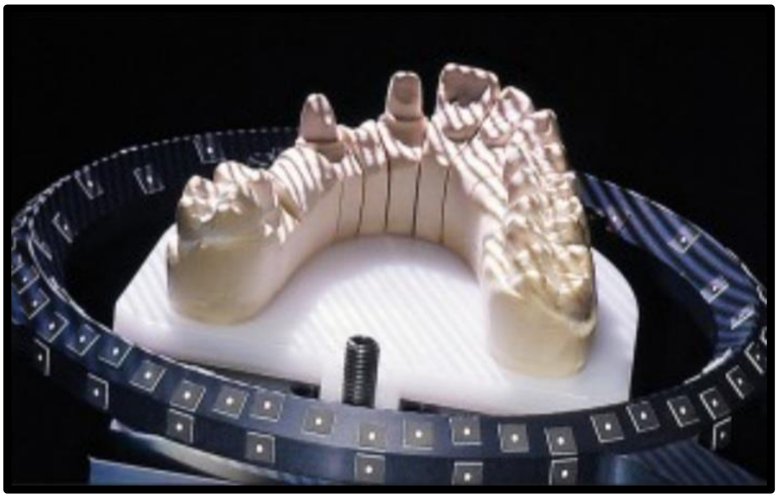

Figure 1.2: LED Based scanner.

II. 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 1.3: Laser Based scanner.

Figure 1.4: A-intra oral

Figure 1.5:B- extra oral scanners

1.4.1.B 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 for 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).**

1.4.2 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).**

1.4.3 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):**

A. 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 technique in recent years can milled any material in any sizes even a complete denture **(Parasher, 2014).**

B. Additive technique (Solid free form fabrication):

This category 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).**

C. 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).**

1.5 Classification of CAD-CAM systems

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

1.5.1 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).**

1.5.1.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).**

1.5.2 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).**

1.6 Clinical and laboratory aspect

Clinical step 1

The first clinical session of denture design consists of three stages: (1) Conventional physico-chemical (with plaster or alginate) maxillary and mandibular primary impressions. Optical impression of the edentulous arch can be performed but its implementation remains time-consuming and its advantages have remained limited up to now; (2) recording of the preliminary inter-arch report by a specific device (Centric Tray®, Ivoclar-Vivadent) (Fig. 1.6). This recording can be performed with alginate or high viscosity silicon; and (3) the UTS CAD® device (Fig. 1.7) is used as a Fox plate to measure deviations from the reference planes (Sagittal Camper and bi-pupillary frontal planes). This device is fixed to the Centric Tray® and digital deviation values are measured and subsequently transferred to a virtual articulator. The main objective of this data recording step is to position the virtual primary models in space **(Bonnet *et al.*, 2017).**

Figure 1.6: centric Tray **(Bonnet *et al*.,2017).**

Figure 1.7: UTS CAD **(Bonnet *et al*.,2017).**

Laboratory step 1

Impressions bound around the Centric Tray® are scanned. Superimpositions of Centric Tray® bound impressions with the primary impressions and values of the UTS CAD® are used to create primary digital models positioned on the virtual articulator. Thereafter, the edges of the individual trays are drawn according to conventional recommendations. A specific software application (3shape) proposed a design for the occlusal rims, which are deliberately reduced in height compared to the dimension of the recorded vertical occlusion. A cutback is integrated to leave sufficient space for the intra-oral center-point recording system (Gnathomètre®) and to avoid any interference between the antagonist occlusal rims (Fig. 1.8). Once the design has been finalized, the project files are sent to the milling machine. The Wieland system comprises two 5-axis machine tools: the Zenotec Select Ion and the Zenotec Select Hybrid. The first is designed only for dry drilling of wax and PMMA (polymethylmethacrylate) resin. It includes air ionizers that facilitate cleaning due to the absence of electrostatic charges in the PMMA particles. The second is used for both dry and irrigated milling. Thus it can be used to drill glass-ceramics (Emax, Empress, etc.) and zirconia. Both machines have an 8-disc loader and do not require any external intervention during the milling step. A new range of milling machines might be proposed by Ivoclar-Vivadent in the near future **(Bonnet *et al*., 2017).**

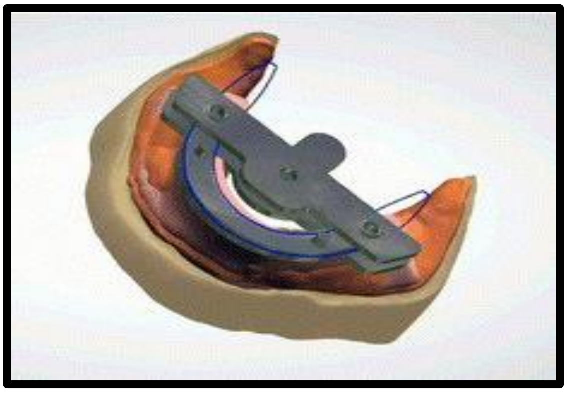

Figure 1.8: A cutback is integrated to leave sufficient space for the intra-oral center-point recording system (Gnathometer®) and to avoid any interference between the antagonist occlusal rims **(Bonnet *et al*.,2017).**

Clinical step 2

Conventional functional impressions are realized with the manufacturing trays, as the depressible nature of the mucosa cannot yet be recorded by optical impression. These impressions will be introduced several times in the mouth. Consequently, the impression material contains some elastic component. The inter-arch relationship could be recorded in the same session. Before clipping the center-point system to the impression trays, the maxillary occlusal rim can be checked with UTS CAD® and its provided fork. Also, an intraoral system with a central supporting point is used (Gnathometer®). A screwing/unscrewing pointer is used to modulate the occlusal vertical dimension. A circular receiving plate with a marker material enables registering the different mandibular movements. Gnathometer® can be easily clipped to tray impressions and does not require bonding or retention (Fig. 1.9) **(Bonnet *et al*., 2017).**

Figure 1.9: Gnathometer® can be easily clipped to tray impressions and does not require bonding or retention **(Bonnet *et al*.,2017).**

Next, the Occlusal Vertical Dimension (OVD) is determined and adjusted by screwing or unscrewing the central pointer. Modifications of the OVD are easy to achieve as the only contact between the maxilla and the mandible is made through the central pointer. This process avoids any interference from the occlusal rims, a likely source of mandible deviation, and allows excellent retention of the impression trays on the ridges. Then, the cylindrical receiving plate of the central pointer is tinted to obtain the mandibular paths (Gysi Gothic arch). These paths meet at an equilibrium area used as a reference during the inter-arch relationship recording step (Fig. 1.10). The use of elastomer material (silicone bites) allows shaping the lip support and locating the horizontal joint line of the lips (Fig. 1.11) **(Bonnet *et al*., 2017).**

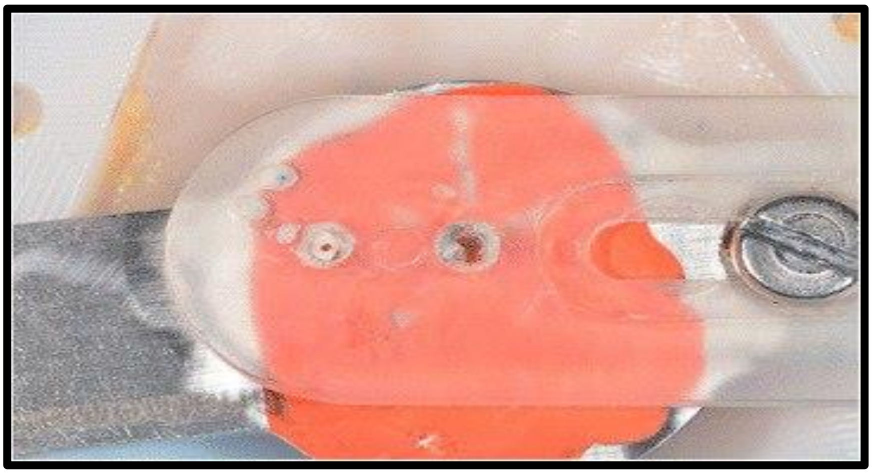

Figure 1.10: Gysi Gothic arch paths meet at an equilibrium area used as a reference during the inter-arch relationship recording step **(Bonnet *et al*.,2017).**

Figure 1.11: The use of elastomer material (silicone bites) allows shaping the lip support and locating the horizontal joint line of the lips **(Bonnet *et al*.,2017).**

Laboratory step 2

Afterwards, the embedded functional impressions are scanned (Fig. 1.12) to obtain the virtual working models. These models are placed on the virtual articulator and the reference points are identified (incisal papilla, canine tooth tips, retro-molar pad centers, limit of the retro-molar pads, tuberosities, etc.) to trace a schematic representation of the Pound area for posterior teeth positioning. Then, the limit of the future denture base is drawn and a teeth setting is proposed by the 3shape software. The software contains a library of teeth of different brands and shapes and a function with an automatic proportional size table between the anterior and posterior teeth. Subsequently, the operator is able to modify every parameter except those for tooth removal. At present, only second molars can be removed, in the case of short arches. The solution proposed by the software for the positioning of the posterior teeth is ideally suited for the morphology of prosthetic teeth, hence facilitating the integration of a bilateral balanced occlusion concept. Once this assembly has been validated, finishing of the virtual waxes must be carried out (Fig. 1.13) to avoid imperfections that could later prevent milling: the software does not indicate these future problems during the design phase **(Bonnet *et al*., 2017).**

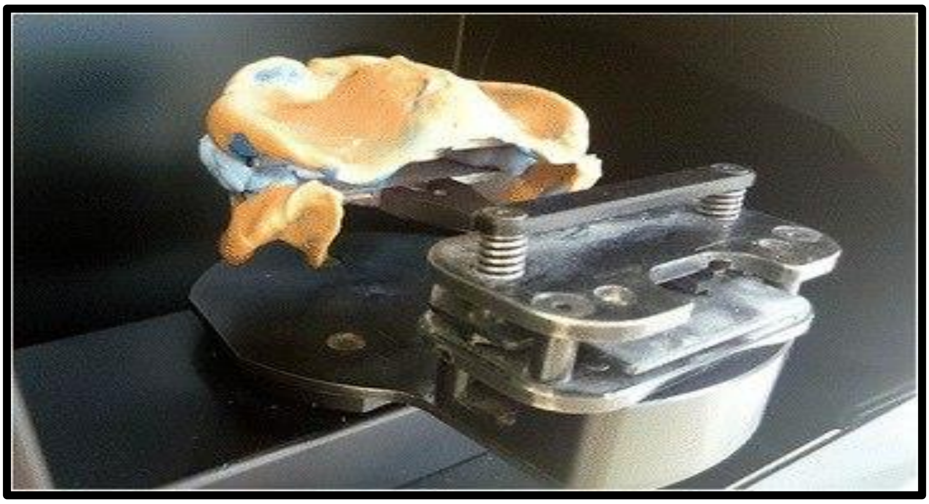

Figure 1.12: The embedded functional impressions are scanned **(Bonnet *et al*.,2017).**

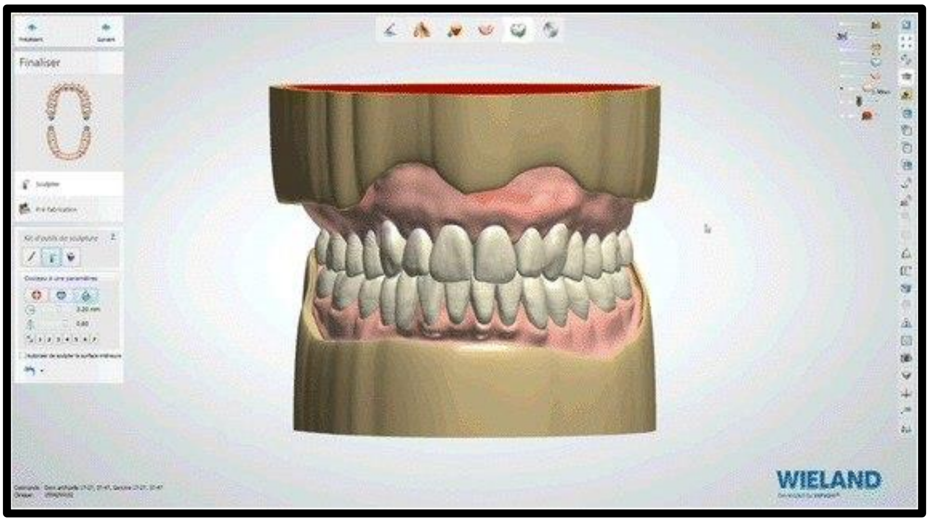

Figure 1.13: Virtual waxes finishing step **(Bonnet *et al*.,2017).**

After reception of the files by the command software of the milling machine (Wieland), the complete denture project (denture bases and prosthetic teeth) is manufactured on a white PMMA disc (Figs. 1.14), leading to the production of a much more useful template than when obtained with the conventional method **(Bonnet *et al*., 2017).**

Figure 1.14: Manufactured template on a white PMMA disc **(Bonnet *et al*.,2017).**

Clinical step 3

During this session, the occlusion rims are validated and patients use their manufactured template for functional validation (masticatory and phonatory) for a while at home. If the patient already wears complementary retention systems (roots or overdenture implants), a retention silicone (for example: Retention.Sil® Bredent®) can be used to replace the intra-prosthetic retention part (Fig. 1.15). Similarly, if the patient has neuro-musculo-articular disorders detected during the clinical examination or the recording of the Gysi Gothic Arc, this template can provide a cheaper rehabilitation solution. In addition, these templates can easily be used as radiological and/or implant guides for a subsequent prosthetic project. After the try-out period, the patient's criticisms are collected and modifications are made if necessary. In cases of significant changes, new templates can be machined. The final step can be initialised after validation of the functional aspect **(Bonnet *et al*., 2017).**

Figure 1.15: A retention silicone (Retention.Sil® Bredent®) can be used to replace the intra-prosthetic retention part if the patient already wears complementary retention system **(Bonnet *et al*.,2017)**

Laboratory step 3

Four steps are necessary to complete the denture: (1and 2) milling of the denture extrados on a pink resin disc with specific alveoli for the prosthetic teeth, depending on the brand and model of the teeth selected (Fig. 1.16). Thereafter, a positioning key is milled to ensure the ideal setting of the teeth during the bonding process with a PMMA resin. (3) Once the bonding is complete, the disc is put back into the machine to mill the denture intrados. If a prosthetic tooth base interferes with the virtual model, it will be machined according to the correct intrados. (4) The denture is removed from the disc, scraped and polished according to the conventional procedure. It should be noted that the surface finish after machining is very satisfactory **(Bonnet *et al*., 2017).**

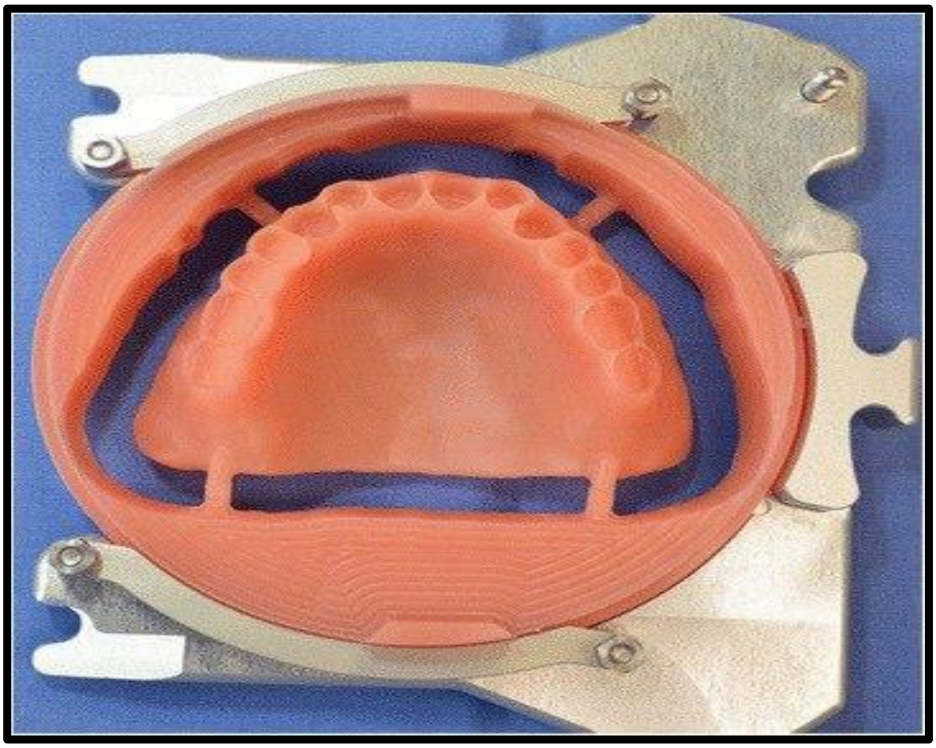

Figure 1.16: Milling of the denture extrados on a pink resin disc with specific alveoli for the prosthetic teeth, depending on the brand and model of the teeth selected **(Bonnet *et al*.,2017).**

Clinical step 4

During this last session, the dentures are tried and primary equilibration is performed. If all the steps have been conformed to and validated, the first equilibration session is often unnecessary or very easy (Fig. 1.17) **(Bonnet *et al*., 2017).**

Figure 1.17: First equilibration session, as all steps are validated **(Bonnet *et al*.,2017)**

1.7 Advantages for the Dentist, Dental Technologist, and Patient

1. Clinical data are recorded in fewer appointments, reducing clinical chair time and—in selected cases—the costs, leading to a higher patient satisfaction. As a side effect, there may be a greater likelihood of the patient to return to the same dentist who has the documentation of all the past data **(Clark *et al*., 2021).**
2. Thanks to the clinical digital data and the software in the dental laboratory, technological steps are accomplished in a shorter time, leading to a more standardized high-quality end product. For the dental technologist, the design of a complete denture is shifted from a manual wax-up and denture teeth set-up to a digital design on a screen, and the fabrication of a complete denture from a manual to a digitally guided fabrication. Both are in a more standardized, controlled, easy, fast, and predictable way **(Srinivasan *et al*., 2019).**

3. The repository of digital data allows any time the fabrication of a spare or replacement denture, the fabrication of a new denture as a copy (duplicate) of the old denture, and an easy rebasing by producing a “new old” denture **(Takeda *et al*., 2020).**

4. In edentulous patients who are in need of implants, the data may be used for a complete digital workfow by designing and fabricating a diagnostic denture teeth set-up, a provisional denture, a radiographic or surgical template that supports the planning and the placing of implants, and, not least, the fabrication of a fnal restoration **(Swamidass and Goodacre, 2021).**

1.8 Disadvantages of CAD-CAM complete dentures

CAD-CAM complete dentures present several disadvantages when compared to conventional processed complete dentures. When manufacturer’s denture teeth are bonded manually to milled denture bases and not adjusted on an articulator, the development of a balanced occlusion will often require a clinical remount procedure to balance the denture teeth. One other disadvantage of CAD-CAM complete dentures to the clinician is that communication with the dental laboratory can be more challenging and may be required multiple efforts to resolve design-related issues. The impact of CAD-CAM on the environment should not be neglected, the milling procedures produce resin particles, which contribute to the plastic pollution of the environment. Similarly, silicone impression materials are not biodegradable. Finally, the logistics require packaging and shipping of dentures that may include international customs procedures **(Baba *et al*., 2021).**

CHAPTER TWO

CONCLUSION

CHAPTER TWO CONCLUSION

2.1 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 final 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.

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