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(Mini review)

Role of Digital Technology and Recent Materials in Removable Partial Denture Fabrication

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ABSTRACT

Removable partial dentures have been used since the 19th century, and research into new materials has made both partial and complete dentures increasingly important worldwide. Computer-aided design and computer-aided manufacturing techniques (CAD/CAM) have recently been developed for removable prosthetics dentistry. CAD/CAM technology is mainly divided into subtractive technology and additive technology. Additive manufacturing technology is defined by the Society for Testing and Materials (ASTM) as "the procedure of assembling matters to create a digital model from 3-dimensional virtual models, usually in the form of increment by increment." In contrast, "additive manufacturing technology" is defined as follows. “Conventional machining” is defined as “conventional machining” using power-driven machines such as lathes, saws, milling machines, and drills to perform various material processing processes. CAD/CAM technology uses a technology that consists of scanning, design, and milling stages. The scanning machine converts the tooth characters into a three-dimensional (3-D) map. The computer tools generate this data into a 3D map. The dentist uses computer tools to design the repair geometry. The computer tool generates the tool path the milling equipment uses to create the desired form from the restoration material.

Keywords: Partial denture, CAD/CAM, Additive technique

1-Introduction

1.1.Removable partial denture as a treatment option

Teeth are necessary for chewing, esthetics, and speech. Losing the teeth results in impaired functions, which results in physiological and psychological trauma to the individual. The progression of edentulism finally leads to a great impact on the quality of life and overall health status of the people. (1)

Removable partial dentures have been used since the 19th century, and the development of new materials has made both partial and complete dentures more widely used. Since then, significant materials, technology, and design improvements have improved the quality of partial dentures. Traditional removable parts offer several advantages, including precision, resistance to deformation, inherent smoothness, and reduced weight and space. (1)

The advantage of partial denture as a treatment option for partially edentulous cases is a cheap, versatile, and flexible treatment modality for partially edentulous arches. Recent changes in dental treatment that favor dentures have reported an increase in the fabrication of dentures worldwide. Methods used in the production of cast partial dentures can be either conventional lost-wax technique or the latest method of digital technology. (2)

The steps involved in constructing a partial denture comprised the abutment teeth examination, preparation of the selected abutments, relating the dentulous spaces to the metallic partial denture framework, communications with the technicians, patient training for continuous recall, and hygiene instructions. Patients who have lost many of their natural teeth due to poor hygiene need much more care and firm instructions to avoid complications. (3)

A conventional removable partial denture also involves impression making, production of the model, surveying the diagnostic, master casts, and designation of RPD components, and excellent interaction between the technician and the dentist, which is a process that is too long and time-consuming. Dental surveying is performed in the laboratories to determine the important characteristics of the dental model for the RPD designation. The role of the surveying procedure is to determine areas of wanted and unwanted undercuts present on the selected teeth, ridge, and soft tissue. (4, 5)

Removable dentures' frames are usually made from alloys, such as cobalt-chrom and titanium alloys, with excellent rigidity and high elastic modulus. These materials were processed

using the conventional lost-wax technique. Recently, computer-assisted design and manufacturing CAD/CAM, using milled frameworks or 3D-printed, is widespread worldwide because it is considered a simple procedure, convenient and accurate design, and their speedy reproduction. [6]

1.2. Recent techniques for partial denture fabrication

CAD/CAM techniques have recently been implemented significantly in maxillofacial technology and partial dentures, including fixed and removable appliances. The term CAD/ CAM is defined as CAD: The use of digital software to virtually fabricate 3D digital format of solid objects. CAD programs can be modified for more complicated applications CAM: fabrication of workpieces with the help of computer software. [7]

CAD/CAM philosophy was introduced to dental fields in 1971 by Duret when the first CAD/CAM prophesies were fabricated. CAD-CAM technology can help in major industrial objects which has made its fabrication much simpler, cheaper, and more rapid. Nowadays, dental CAD-CAM technology has gained popularity abroad due to multiple factors: time-saving, more accurate reproducibility, and long-term durability. [8]

Now (CAD/CAM) technology is widely used in dental practice, most commonly for manufacturing implant prostheses and appliances, fixed restorations, crowns, onlays, inlays, and removable prostheses. CAD/CAM technology has been recently introduced in the fabrication of complete dentures, which added many advantages over conventional fabrication techniques. It facilitated a reduced number of recalls and the fabrication of spare dentures more easily and more rapidly, as the data required for its fabrication are pre-saved; the laboratory work can be done more rapidly and at less cost in the long run. [9.10]

To avoid conventional techniques and disadvantages, digital workflow using (CAD-CAM) technology may be considered a rapid accurate alternative with high precision and accurate results. Indeed, the use of CAD/CAM technology in partial and complete denture fabrication has helped to enhance the accuracy, adaptation, retention, and aesthetics of the final prosthesis while helping reduce the cost and number of periodic recalls, improving patient satisfaction. Numerous approaches have already been developed for manufacturing complete dentures and partial dentures using scanning technology via intra-oral scanners and digital technology. The problems of using these new technologies for immediate dentures are still unresolved due to the difficulty in matching

the size, shape, and color of the artificial teeth to those of the neighboring teeth. Furthermore, there is a shortage of software that can be able to produce immediate dentures. [11]

The CAD program could demarcate areas of undercuts either wanted or unwanted, those could be marked in the form of the digital color map from the buck digital cast. However, some studies claimed that removing unnecessary undercuts relied on determining the path of insertion by conventional techniques with the dental surveyor is time-consuming compared to a digital surveyor. [12]

Advances in CAD/ CAM technology reduce the manufacturing period of dental restorations and ensure high-quality results. Dimensional inaccuracy in the prosthesis properties and/or prosthesis volume is reduced by CAD/CAM technology in comparison to the conventional techniques. The significance of using CAD/CAM technology in developing removable partial dentures is spotted in the digital determination of the insertion and withdrawal path, the immediate removal of unwanted undercuts, and the quick identification of the wanted undercuts. Not only is it a time-saving procedure with less risk of human errors, but the CAD/CAM technology also ensures automatic reproducibility, which helps decrease human errors and enhances quality control in the dental field. [13, 14]

Digital surveying of a digital cast facilitates a virtual imagination for a designed partial denture to be done on the digital screen based on the basis and guidelines of removable partial dentures. [15].

The CAD program was uniquely able to determine the undercuts, which could be marked in a different color screen on the virtual cast. CAD/ CAM digital programs can help determine the insertion path and automatically eliminate unwanted undercuts. It also contains a Library of different features and components. Doctors can simply “drag and drop” the selected removable partial denture components in digital buck cast with a simple raid process. Recent studies reported that the introduction of digital techniques to perform the process of surveying and designing the components of removable partial dentures uses CAD/CAM software and manufacturing of RPD framework pattern by a unique system mixing CAD/CAM/RP technologies. [16]

Quality control features built into digital CAD software can help control the dimensional changes that occur during the metal casting procedure. The time required for the software to draw survey lines can be done in seconds using digital CAD/CAM. This cannot be compared to the time required to manually survey cast [17.18]

CAD/CAM technology involves a step-by-step intra-oral or extra-oral scanning, designing, and milling process. A scanning device converts the scanned data into three-dimensional (3-D) voxel units. Computer software converts this data into a digital 3D map. The operator designs the desired shape of the prediction using software tools that create tool paths used by the milling machine to create the designed shape. A CAD/CAM system comprises three main parts: (1) Data acquisition tools. Selected data from teeth, adjacent and opposing soft and hard tissues are collected and converted into digital data. This procedure can be done via an intraoral scanner or indirectly via a stone model created by making a traditional impression with a desktop scanner. (2) various software programs for designing virtual restorations on a virtual working model. [19]

Such technology introduces a raised importance to the dentist and the patient. Fabrication of complete or partial dentures has required five appointments minimally involving a lot of work from the dentist and technicians with multiple visits from the patient. Dentures fabricated by CAD/CAM digital software can be completed in as few as two visits, which helps save a lot of time and effort. Patient conventional data are digitized and stored through the software.so, when a patient fractures or loses his denture, new and identical dentures can be fabricated easily and rapidly without making new clinical records [120].

A CAD/CAM technique involves a staged process of scanning, intraoral or extraoral, designing, and milling stage. The scanning device converts scanned data into three-dimensional (3-D) units of voxels. The computer software translates this data into a 3-D digital map. The operator designs the desired shape of the prophesies using the software tools, which creates a tool path, that the milling machine will use to create the designed shape. [21]

CAD/CAM systems are divided into three stages: (1) data acquisition stage, which collects the selected data from the natural teeth, adjacent and opposing soft and hard tissues, and then converts them to digital data. This procedure can be done through intraoral scanners or indirectly using a stone model generated through making a conventional impression via the desktop scanner; (2) varieties of software for designing virtual restorations on a virtual working cast; and (3) fabrication of different types of restorations. [21]

Advantages of digital fabrication of dentures

- Reduced restoration operation time.
- Reduces the risk of bacterial colonizing the prophesies surface.

- Facilitate the standardization of academic research on removable prostheses.
- Easily reproduce prostheses and create trial prostheses based on stored digital data.

Limitations and disadvantages of digital fabrication of dentures by CAD/CAM technology:

- Manufacturing challenges caused by impression-taking, jaw relation recording procedures, and lip support maintenance are similar to the procedures used in the conventional process.
- Inability to define the mandibular occlusal plane.
- Expensive materials and increased laboratory costs compared with those for conventional methods.
- Increased expenses for machines for manufacturing different restorations. [22-25]

1.2.1. Subtractive method

The subtractive method is defined as a "type of recent machining technique that utilizes power-driven machines, such as drill presses, saws, milling machines, and lathes, to perform various material processing processes. These involve physically removing or subtracting the materials with cutting tools to achieve the selected shape and geometry". [30]

Elder CAD/CAM systems rely mainly on subtractive techniques, which depend on(CNC), a computer numerically controlled system, for cutting the selected geometry from a prefabricated blank using subtractive manufacturing technology, including CNC machining. This technology helped in the development of different dental restorations such as onlays, crowns, inlays, and posts. The digital software converts the digital geometry into a tool path system for the CNC machine. This is done by calculating orders' assets that determine the CNC milling process, including orientation, differentarmamentariums used, tool movement, and direction and number. Because of the unequal of character of dental prophesies, the different milling machines combine tools with various shapes and sizes. The tool positioning precision must be within a range of 10m. The CAM software also includes a cutter diameter compensation step to ensure that the milling tools reach the desired selected shape without wasting excessive material. [22, 23]

Dental CNC devices consist of several parts to perform a 3D milling of different prostheses. The milling tools evolve in harmonized three axes (x,y, and z). Therefore, 3-xis milling has the benefit of the least calculation time. Unless the sample used for dental purposes is rotated 180 degrees, machines cannot produce different dental features such as divergence, convergence, and or

mill all the surfaces. The subtractive digital techniques include spark erosion technology and subtraction technology. [24]

Spark erosion is referred to as a subtractive process in metal manufacturing in which sparks are used to extract material from a metal blank into a designed shape under specific circumstances. Milling technology includes diamond grinding and subtractive carbide milling, which are currently used together in chair-side equipment and laboratories. The latest technique to be transferred from manufacturing to the dental field is laser milling technology, which was introduced in early 2015. Milling technology mainly relied on the characteristics of the machine, including dimensional stability and functionality of the milling axis.3-direction X, Y, Z refers to his 3-axis milling equipment, 3-direction X, Y, Z, and clamp bridge refers to his 3-axis milling equipment. A 4-axis milling machine and a clamping bridge with three spatial directions X, Y, Z, and milling spindles, are considered a `5-axis milling machine. [25]

1.2.2. Additive method

Additive digital technology is identified by the help of the American Society for Testing and Materials (ASTM) as “the process of assembling matters to produce a 3dimentuinal object from 3dimentionsal digital model in the form of increment by increment, in contract to subtractive technology, Additive fabrication technology has also been known as a popular method for rapid prototyping, making it feasible for the accurate, customized prostheses needed in the field of dentistry. The increasing need for this technology in general manufacturing is evidenced by the fact that the market is expected to quadruple its size to reach approximately 5 billion dollars by 2030. [26, 27]

A wide range of manufacturing techniques and materials in additive manufacturing are currently under investigation on their uses in dental and medical fields; the production of bio models for simulation, diagnosis, treatment planning, and surgical phases appears to be widely used applications of additive techniques, then the uses for direct fabrication of implantable machines. In the Implantology and maxillofacial field, advances in imaging technology (CT and MRI) have improved the capacity to scan objects with high precision before any invasive surgical procedure. There is a possibility of eliminating the manual handling of special agents in various processing steps; some refer to this approach in dentistry by the term “digital workflow. The basic requirements for a digital workflow are based on three elements. The first is data collection, such

as various scanning technologies. The manipulation and processing of data follow this. Data produced using computer-aided design (CAD) software was finally manipulated and processed to manufacture selected prophesies with desired shapes and from selected suitable materials through computer-aided manufacturing (CAM). [28,29]

Since the 1990s, the dental field has employed prototyping technology, which Charles Hull first presented in the late 1980s, to create anatomical models for surgical procedures. One-of-a-kind prototyping technology, 3D printing, may be combined with CAD software and other digital data and is thought to require less money in terms of materials and machinery than other methods. There are now two primary methods for manufacturing removable partial dentures: the first involves creating a wax or resin sacrificial template cast in metal. [30,31] 3D printing is considered a recent prototyping technology which considered approximately with reduces material expenses and machines over the other techniques and can be integrated into CAD software and other digital workflows. Currently, there are two different main techniques used in the manufacturing of removable partial dentures; the first is to fabricate a sacrificial pattern made of resin or wax, after which this specimen is cast to be a to metal frameworks, and the second technique is the manufacturing of metal frameworks directly by selective laser melting technology. [32]

1.2.2.1- Selective laser sintering

Selective laser sintering and selective laser melting are considered additive manufacturing technologies where the laser beam can be used for sintering or melting the metal to create a solid object guided by a 3D virtual model. The major difference between both techniques is that in selective laser sintering, 3-D objects can be produced from the fusion of metal powder through the laser beam in contrast to selective laser melting technology, where the metal particles are melted through the laser beam. Selective laser sintering technology is much more common in the dental field; different materials, such as polymers, metal alloys, and wax, can be utilized with selective laser sintering. Both techniques are now used to fabricate partial denture frameworks, which helps reduce the number of steps used for casting metals with more precision. [33]

The laser-sintering fabrication method is composed of computer-aided design (CAD) of any object. It is manufactured using a high-intensity laser beam, which is used to adhere to metal

particles increment by increment. Laser-sintering technology facilitates the rapid manufacturing of complicated objects with excellent accuracy and at a low cost. [34]

Laser-sintering technique is sub-categorized into more specialized techniques, such as selective laser melting (SLM), and selective laser-sintering (SLS). SLM is a complete melting of metal particles; on the other hand, SLS includes incomplete melting of a portion of the material particles, including fusion within the particles' border. The major dissimilarity between SLS and DMLS is, that in the Selective laser sintering technique, particles may be metal or different materials like polymer and the particles only partially melt during the sintering procedure, on the other hand, DMLS combines a mixture of metal particles which have different melting points. During the DMLS procedure, the particles with the lower melting point completely melt; conversely, the particles with a high melting point partially melt. [35]

1.2.2.2-Stereo lithography,

One of the most widely used rapid prototyping techniques is stereo lithography, a machine produced by Charles Hullin in the 1980s. This machine was available in the dental market for the first time by 1980. The concept behind its development is a photosensitive monomer resin, which units to form a polymer and becomes a solid when expressed by ultraviolet (UV) rays. [35]

The AM system was originally developed by Swainson in 1990 and patented in 1971 under the name Photochemical Processing, but it had some inevitable drawbacks. After many years, the first known in-market CT machine was developed. In 1981, Kodama described an automated technology for creating these step-by-step layered 3-dimensional digitally designed models using a photosensitive device as a stereolithographic technique. [36]

The improvement in digital technology and materials has enabled the implementation of three-dimensional (3D) modeling protocols in the dental field over the past 25 years. Stereolithographic models have gradually become popular in the treatment of craniofacial anomalies and implant rehabilitation, replacing traditional milling models and radiographs. Several benefits include better visualization of complex anatomy and more accurate and refined preoperative planning with simulated insights into targeted procedures. This review aims to provide important information on stereolithography's various applications and limitations. It is

aimed at general dentists and dental students who wish to gain experience in the field of reconstructive surgery and implant placement. [36]

1.3. Recent materials for partial denture fabrication

The main functions of removable partial dentures (RPDs) are the protection of the remaining natural structures and; the enhanced chewing procedure and aesthetics. Under masticatory load, different naturally occurring forces act on the removable partial denture which in turn resulting in movement of the denture base, this results in the destruction of the supporting tissues and patient discomfort. Therefore, all attempts should be considered to control this load carefully. Distal extension removable partial denture bases show different support types on the natural remaining teeth and residual alveolar ridges. The abutment next to the distal extension base is exposed to anteroposterior and lateral forces, plus the rotational forces clasping system will transfer these loads to the natural teeth. They may result in the premature collapse of its supporting system. [36]

1.3.1 Base-metal alloys

Base metal alloys were the most commercially used metal alloys in dentistry because they are cheaper than gold alloys, have better mechanical characteristics, are lighter in weight, and are more rigid. Cobalt-chromium, nickel-chromium, and nickel-titanium alloys are the dental field's most widely used base metal alloys. [37]

Cobalt chromium has been used for many years for partial denture framework fabrication and the framework of different dental appliances. Its worldwide popularity for many years has returned to its high strength, availability of casting machines, and lightweight, not biocompatible. On the other hand, its bad esthetics return to metal display and human errors during multiple laboratory steps and casting procedures considering its major drawbacks. [37,38]

Now, using CAD/CAM technology to fabricate removable partial dentures from cobalt chromium eliminates casting problems and minimizes human errors, improving the quality of partial dentures.

The hybrid technique for partial denture fabrication, which starts with the digital design of the partial denture framework and then is completed through the conventional casting procedure, provides higher results due to decreased human error factors. [38]

1.3.2- Titanium

Titanium alloys have notable applications used in the dental field, which return to their shape memory and excellent elastic characteristics, in addition to many excellent characteristics of pure titanium, such as lightweight, good fit precision, and biocompatibility. Nickel titanium is a titanium alloy with the unique character of recovering from elastic deformation and remains constant up to its proportional limit. [39]

Titanium has gained broad worldwide due to its biocompatibility, low-weight corrosion resistance, and high mechanical properties. Milling of framework from titanium is still challenging to the dentist due to the long milling time and rapid wear of the milling burs. [40]

1.3.3 Thermoplastic materials

Thermoplastic materials can be used in the dental field to fabricate preformed retainers, metal for removable partial dentures free from metal, artificial teeth for removable partial dentures, and occlusal stents. Perhaps adding chemical improvement to elastomeric dental materials will expand the range of clinical uses of thermoplastic materials in dental practice and thermoplastics in the dental field. [41]

1.3.4 Acetal resin

Acetal resin (semi-crystalline polyoxymethylene-based resin) is a monomer-free, crack-resistant thermoplastic material. It has many ideal properties, such as adequate flexibility, high elastic memory, high tensile strength, and high wear resistance. It does not require regular adjustment to maintain ideal contact with the tooth surface. It is also elastic enough for the bracket to stay in more deep undercuts. Additionally, acetal resin has excellent fracture resistance, wear resistance, and tooth-colored aesthetic characteristics. [42]

Acetal resin material is considered one of the most thermoplastic materials used in removable partial denture fabrication due to its good esthetics, low weight and biocompatibility, decreased elastic modulus, and high flexibility, which facilitates high retention due to its ability to engage tooth undercuts.

Acetal resin clasps with different shades, like the color of natural teeth, can be used with a conventional cast metal framework to improve its esthetics and patient satisfaction. The main drawback of clasps made from acetal resin is the bulk of the clasp, which results in more contact with natural teeth, resulting in plaque accumulation and periodontal problems.

Removable Partial dentures fabricated from polyimides lack teeth support due to the absence of rests. Recent studies suggested that polyimide nylons can be used with metal framework. The major drawbacks of Acetal resin surface roughness which is higher than the poly methyl metha acrylate and color instability.

1.3.5. Polymethyl methacrylate

Poly-methyl methacrylate (PMMA) is widely used in prosthetic dentistry and dental practice, such as fabricating artificial teeth, dentures, orthodontic retainers, temporary or temporary crowns, denture bases, and denture restorations. Other dental uses for Poly methyl-meta acrylate include occlusal splints, printed or milled castings, molds for treatment planning, and implantation of tooth samples for research purposes. PMMA has become a popular material used in the dental field. It is suitable for these dental applications due to its unique properties such as low density, beauty, cost-effectiveness, ease of handling, and customizable physical and mechanical properties. Different chemical modifications and physical and mechanical updates using different types of fibers reinforcing materials and nanotubes have recently been developed to improve further the properties of PMMA (thermal properties, water absorption, solubility, impact resistance, and flexural strength). [(42)]

1.3.6. Heigh performance polymers (PAEK)

The fabrication technique for poly aryl ether ketone (PAEK) polymers is extremely popular nowadays. The planning of PEKK was, to begin with, depicted within the 1960s. Look may be a tall execution of semi-crystalline, non-homogeneous thermoplastic fabric. This fabric offers one of the most elevated strength-to-weight proportions accessible in a

Polymer. Their mechanical and physical properties are tall(solid scraped spot resistance), chemically safe, and have a tall degree of warm and dimensional stability with excellent flexibility and modulus comparable to that of bone. [(42)] So, digital technology plays an important role in the fabrication of partial denture frameworks, from diagnosis to insertion.

2. Conclusion

Digital technology can be a unique alternative to conventional technology, especially with the development of new materials, which in turn helped to overcome the drawbacks and increase the long-term success of the fabrication of removable partial dentures.

- **Conflict of Interest**

  No conflict of interest.

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