Review Article

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Digitalization of Conventional Removable Prosthesis : CAD-CAM Dentures.

Abstract:

During the last few decades significant advancements in the field of technology have been integrated in our day to day life. In the medical field and more specifically dentistry, one of the novel applications of robotic technology is the use of Artificial Intelligence in prosthodontics. Newer technologies have been consistently developed based on the principles that try to simulate the human brain functioning to develop solutions that do not just follow preprogrammed instructions, but also have some traits of the human's such as the reasoning ability and experienced learning from practice without being programmed manually. Integrating CAD/CAM technology into removable denture designing and fabrication has helped in improvement of the quality of the dentures and simplification of the laboratory work. Manual laboratory procedures are either reduced or eliminated, thus enabling the dental technician and the dentist to ensure reproducibility and accuracy of prostheses. This reduces overall time required in patient rehabilitation. This article presents a critical review on the application of CAD- CAM technology in removable prosthodontics and possible research directions in this field in the future.

Keywords : 3D models, CAD-CAM, complete dentures, digital dentures, prosthesis.

Introduction

One of the most commonly used treatment modality for prosthetic rehabilitation of completely or partially edentulous patients is removable prosthesis. Various methods and materials have been historically proposed for the fabrication of complete or partial dentures. Acrylic resin-poly methyl methacrylate (PMMA) was developed as in the 1930s and by 1940, 90 to 95 % of all denture bases were made using this material[1]. Even today, PMMA is the most commonly used denture base material. The process of denture fabrication with heat polymerized poly methyl methacrylate resins is technique sensitive and consists of several laboratory steps which require attention to detail and thus can be very crucial in the ultimate performance of the denture in the clinical situation. Clinically optimal dentures by minimal repetition of laboratory steps require good coordination and cooperation between the experienced dentist and the skilled technician. Relying solely on skills of laboratory personnel particularly with the manual conventional methods for denture fabrication, poor adaptation of dentures is more frequent and this may affect patient's satisfaction with the new prosthesis, though the feedback by the patient is often under reported[2].

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Computer-aided design and computer-aided manufacturing (CAD-CAM) has evolved as a new approach for the designing and fabrication of prosthesis, both removable and fixed[3,4]. In addition to the success of computer-aided design and computer-aided manufacturing (CAD/CAM) employed on a large-scale in dentistry [5,6] along with a shortage of qualified dental laboratory technicians [7] made CAD/CAM accessible with a variety of techniques available for the fabrication of the dental prostheses.

Artificial Intelligence–How Does This Work?

Artificial intelligence (AI) is a branch of computer science concerned with building smart software or machines capable

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of performing tasks that typically require human intelligence [8,9]. It is commonly defined as "the ability of a system to interpret external data, learn from them, and use those learnings to achieve objectives and goals through flexible adaptation" [8,9]. Machine learning, as a subset and foundation of AI, is the ability of computer systems to perform specific tasks to approximate human cognition, without using explicit instructions, solely relying on patterns and mathematical models [10].

Computed aided designing software can aid the dentist to design the best possible functional and aesthetic prostheses. In dental implantology, it can play a major role in identifying the type of bone and thickness of cortical bone for making precise surgical guides for placing implants.[11]. Another breakthrough is that the time consuming and laborious process of the conventional casting method has been replaced by CAD/CAM technology resulting in reduced human errors. [12].

Designing Virtual Complete Dentures

Digital complete dentures are successfully designed using the software through several steps including creation of 3D digital edentulous models, study and analysis of model, artificial teeth arrangement, reducing the relief areas, and adjustment of occlusion. Artificial teeth and record bases are successfully fabricated according to the designed virtual complete dentures using milling machine controlled by a CAM software. Bonding the physical dentitions to the corresponding denture bases generates the final physical complete dentures.

With this CAD-CAM technology, patients require only two appointments to get their complete dentures. All impressions, jaw relations, selection of teeth, and maxillary anterior teeth positioning can be completed in patient's first visit, saving a lot of time and materials for both patients and/or dentists.

Kattadiyil et al in 2015 conducted a prospective clinical study to compare clinical treatment outcomes, patient satisfaction, and dental student preferences for digitally and conventionally processed complete dentures in a pre-doctoral setting. Fifteen completely edentulous patients received each, one conventional set and one digital set of complete dentures. After wearing each denture for 1 week, patients reported overall higher satisfaction with digitally fabricated denture in terms of retention and stability [13].

Fabrication Process of Removable Dental Prosthesis Using Computer-aided Design / Computer - aided Manufacturing

The first removable prosthesis was manufactured by Maeda et al in 1994, it was based on 3D lithography[14]. Subsequently, Kawahata et al in 1997 improved the removable prosthesis duplication technique by using computerized numerical control (CNC) system and ball-end mills [15].

Technological advancements and subsequent developments have allowed the use of different systems, such as milling and rapid prototyping with CAD-CAM technology for making removable prosthesis[16].

Complete Denture Fabrication

1. **Preparation of edentulous final cast, and wax occlusal rims with record bases.**
   Using either conventional impression technique or intraoral digital impression technique, models are prepared. For digital impression, 3D image is developed by the dentist using a high speed, high density, small size, and multifunctional device [17].The precision of digital impressions has been studied by several researchers and it has been found that though the use of digital models is a relatively new technique, it has an accuracy of up to 10 μm, and the models have been found to be as reliable as traditional stone casts[18].

2. **Creation of three-dimensional digital edentulous models.**
   A 3D laser scanner is used to scan the physical master cast and wax occlusal rims with record bases to obtain three separate 3D digital models, including maxillary and mandibular master cast, and maxillary occlusal rim with maxillary record base, and mandibular occlusal rim with mandibular record base.

3. **Maxillo-mandibular relation transfer and model analysis using CAD.**
   Three points are selected on the contacting plane of the maxillary and mandibular occlusal rim on 3D digital edentulous model. The selection of these three points will determine the occlusal plane for the digital edentulous model. Occlusal points are selected at the maxillary tuberosity, center and canine region with respect to

maxillary arch, and the retromolar pad, center and canine area in relation to mandibular arch. The margin lines(borders) of the denture bases are designed to meet the requirement for complete denture.

4. Arrangement of artificial teeth.

Teeth of appropriate size and form are selected and virtual teeth arrangement is done. Teeth can be moved in sagittal, horizontal and coronal planes and the labio-lingual, mesio-distal and cervico-occlusal dimensions of teeth can be adjusted. An individual tooth can be modified or adjusted either as a whole or even in some particular area.

5. Reducing the relief areas.

After finishing the arrangement of artificial teeth, relief is given for the maxillary zygomatic process, maxillary tuberosity, incisive papilla, mandibular external oblique ridge, and the mylohyoid ridge, according to the requirements for complete denture. This results in local defects on the denture bases and gingiva of the designed virtual complete dentures. These local defects are corrected on the virtual denture bases and gingiva using sculpt and morphing tools.

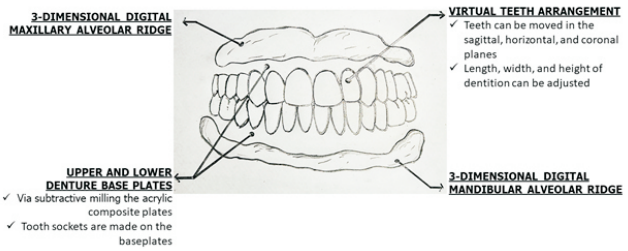
6. Occlusal adjustment.

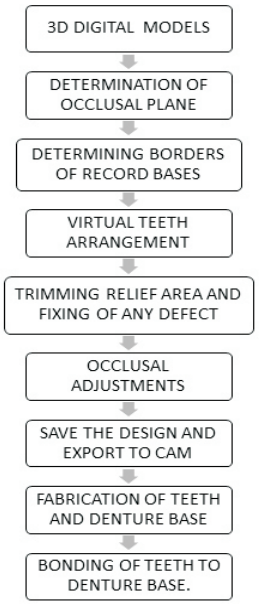
The CAD software can mimic various mandibular movements including protrusion, retrusion and side shift. Adjustable The parameters which can be adjusted on these virtual articulators are occlusal plane, right and left Bennett angle, right and left condylar inclination. Contact points obtained in occlusion during each single movement are recorded using different colors. Any interferences are removed using the function of virtual grinding. This completes the desgning of virtual complete dentures.

7. Complete denture fabrication.

The designed virtual complete dentures are exported to the CAM software which controls a milling machine. The acrylic composite plates are milled into maxillary and mandibular denture bases, and maxillary and mandibular teeth using the subtractive manufacturing technique. After the denture bases are made, tooth sockets are created for bonding the teeth to them. Maxillary teeth are bonded to maxillary denture base and mandibular teeth to the mandibular denture base to complete the fabrication.

Digital Denture – Diagrammatic Representation





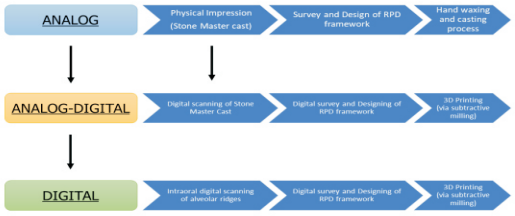
Steps for Designing and Fabrication of Complete Dentures by CAD-CAM

Fabrication Of Framework For Removable Partial Denture Prosthesis

As the removable partial denture has various components and the designing depends on the type of clinical situation, the 3D designing of RPD framework is more time consuming and complicated. Designing of the removable partial denture framework generally consists of designing the major connector, direct retainer, indirect retainer, minor connector and record base[20].

Initially, the conventional or digital impression technique is used to prepare the cast. If conventional impression technique is used, the casts obtained are scanned by using a digital scanner. Then, the path of insertion of the RPD is defined digitally, followed by designing of each component of the framework either by the dentist or dental technician. Finally, digitally designed metal RPD framework is produced with rapid prototyping[21].

Flowchart Comparing Analog and Digital Fabrication of RPD Framework



Advantages of CAD-CAM Dentures

1. Reduction in the number of patient's appointments.
2. Reduction in the clinical chair time for the fabrication of complete denture.
3. Easier to save the collected data, images, and teeth arrangement digitally which can be used for fabrication of an additional denture or a surgical/radiographic template in the future.
4. Reduction in human errors due to conventional laboratory procedures which depend on expertise and skill of an individual dental technician or dentist.
5. Use of pre-polymerized acrylic resin for the fabrication of the denture base provides a superior adaptation and strength as compared to conventionally processed bases.
6. Pre-polymerized acrylic resin (PAR) contains less residual monomer and is more hydrophobic than the conventionally processed acrylic resin. It reduces the potential for infections because less microorganisms attach to the denture bases.

Disadvantages of CAD-CAM Dentures

1. Difficulty in achieving balanced occlusion in complete dentures, the most ideal occlusal scheme for edentulous patients using the software.
2. There is absence of trial denture appointment, an important step in evaluating esthetics, phonetics, correct horizontal and vertical relations, and occlusion. This itself can necessitate more adjustments later on.
3. Use of this technology is more expensive and thus increases the cost of prosthesis as compared to conventional method.

Conclusion

The use of dental robots, especially in prosthodontics, can be a reality in future. The quality of the dentures can be improved, the laboratory work can be simplified and errors due to human variables can be minimized by the integration of CAD-CAM technology in designing and fabrication of removable prosthesis. Due to reduction or elimination of time consuming manual laboratory procedures, resulting prosthesis are more accurate, efficient and can be fabricated in less time. Artificial Intelligence systems can prove to have a pivotal role in prosthodontics but it should be noted that human biological system is more complex, these advancements in technology can be beneficial only it works cohesively with human mind. AI can only assist the clinician in performing the tasks efficiently, but in no way replace the intellect of the human knowledge, skill and treatment planning.

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