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CAD/CAM in prosthodontics: A gate to the future

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Abstract
Recently CAD/CAM technology has been introduced to many fields of dentistry including the field of Prosthodontic dentistry. And its use is advancing every day, but at the same time there is advantages and disadvantages to the use of this technology. In this article we try to summarize some important and basic information about the use of CAD/CAM technology generally and specially in Prosthodontic dentistry.

Keywords: CAD/CAM- prosthodontics- Implant - surgical guides- maxillofacial

Introduction
CAD/CAM is an acronym for Computer-Aided Designing and Computer- assisted Manufacturing [1]. Computer-aided design (CAD)/computer aided manufacturing(CAM) is a field of dentistry and prosthodontics using CAD/CAM (computer-aided design and computer-aided manufacturing) to improve the design and creation of dental restorations, especially dental prostheses, including crowns, crown lays, veneers, inlays and onlays, fixed bridges, dental implant restorations, dentures (removable or fixed), and orthodontic appliances [2, 3]. Computer-aided design and manufacturing were developed in the 1960s for use in the aircraft and automotive industries [2]. The use of CAD/CAM technology in the field of dentistry could be traced back to the 1980s [4]. CAD/CAM technology was introduced in dentistry in the year 1989, by Mormann & Brandestinni in Germany and today it is widely used in all the branches of prosthodontics [5]. Using these CAD/CAM technologies, various types of restorations and dental prostheses can not only be designed but also machined with accuracy and precision. Over the past 25 years, CAD/CAM technology has become extremely popular [1]. The introduction and evolution of computer aided designing and manufacturing (CAD/CAM) technology in dentistry has greatly revolutionized treatment concepts and prostheses fabrication. Although, this technology has been well established in fixed prosthodontics, it is still an emerging science in the field of removable prosthodontics [6]. Computer-aided design/computer-aided manufacturing (CAD/CAM) of complete dentures was introduced following the success of CAD/CAM in implant and fixed prosthodontics [7]. Computer-aided design and computer-aided manufacturing (CAD/CAM) has emerged as a new approach for the design and fabrication of complete dentures [8]. The use of CAD/CAM was limited in the production of complete dentures due to the lack of suitable CAD software until recently [9].

Advantages of CAD/CAM systems
- No Traditional Impressions.
- Produce Chair-side Restorations.
- Less appointment.
- High Precision and Accuracy.
- Improve the Qualities of Restoration.
- Eliminates the Use of the Laboratory Equipments required for Conventional LOST-WAX technique.
- Speed, ease of use, and quality Digital scans.
- Faster design and fabrication.
- Natural appearance CAD/CAM restorations.

Limitations of CAD/CAM systems
- Initial High Cost of CAD/CAM Systems.
- Time and Cost Investment to Master the technique [10, 2].

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CAD/CAM Components

Scanners: Currently, the data acquisition is either performed directly in the patient's mouth (intraoral) or indirectly after taking an impression and fabricating a master cast (extraoral) [11]. Basically there are two different scanning possibilities:

Optical scanners

The basis of this type of scanner is the collection of three-dimensional structures in a so-called 'triangulation procedure'. Here, the source of light (e.g.: laser) and the receptor unit are in a definite angle in their relationship to one another. Through this angle the computer can calculate a three-dimensional data set from the image on the receptor unit. Either white light projections or a laser beam can serve as a source of illumination [12, 13].

Mechanical scanners

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. 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 systems [14].

Design software

Software that can turn the captured images into a digital model to produce and design the prosthesis. Special software is provided by the manufacturers for the design of various kinds of dental restorations. The software of CAD/CAM systems presently available on the market is being continuously improved. The latest construction possibilities are continuously available to the user by means of updates. The data of the construction can be stored in various data formats. The basis therefore is often standard transformation language (STL) data.9 Many manufacturers, however, use their own data formats, specific to that particular manufacturer, with the result that data of the construction programs are not compatible with each other [12].

Digital fabrication process tools

The last phase of the dental CAD/CAM process involves developing a restoration from a CAD model into a physical part that undergoes processing, finishing, and polishing before being inserted into the patient's mouth. The two primary methods used to fabricate these restorations may be subtractive (milling and grinding) or additive manufacturing (Rapid Prototype, RP or 3D printing). Milling/machining technology is a type of restoration fabrication that utilizes subtraction manufacturing technology from large solid blocks. The milling units are categorized into two classifications: (A) dry/wet/milling and grinding in which some milling materials need dry milling and others need wet milling (B) number of axes (3 axes or 4 axes or 5 axes) in which both the 4 axes and 5 axes move linearly up and down through different axes (X, Y, Z). Additive manufacturing is defined as the process of joining materials to make objects from 3D model data, usually layer upon layer. Once the CAD design is finalized, it is segmented into multislice images. For each millimeter of material, there are 5–20 layers in which the machine lays down successive layers of liquid or powder material that are fused to create the final shape. This is followed by further refinement to remove the excess material and supporting frame. The main problem with this type of manufacturing is that it can cause differences in the final model production because of shrinkage during building, postcuring, and minimal thickness of the layers. There are several techniques that can be involved in the additive technology including Direct Metal Laser Sintering (DMLS), Stereo Lithogr Aphy (SLA), Scan, Spin and Selectively Photo curing (3SP), Poly Jet, and Direct Light Projection (DLP). The primary difference is related to developing the z-plane, which represents the vertical components of the restorations [15].

CAD/CAM systems in dentistry

Depending on the location of the components of the CAD/CAM systems, in dentistry three different production concepts are available:

1. Chairside Production/Office-Based Devices
2. Laboratory Production
3. Centralized fabrication in a production center.

Chairside/office production

All components of the CAD/CAM system are located in the dental clinic. Fabrication of dental restorations can thus take place at Chairside without a laboratory procedure. The digitalisation instrument is an intra-oral camera, which replaces a conventional impression in most clinical situations. This saves time and offers the patient indirectly fabricated restorations at one appointment [12]. Four products are presently available for digital impressions in the dental office: CEREC AC (Sirona, Charlotte, NC, USA), E4D Dentist (D4D Technologies, Richardson, TX, USA), iTero (Cadent, Carlstadt, NJ, USA), and Lava COS (3M ESPE, St Paul, MN, USA). Taking digital impressions allows dentists to do away with selecting trays, mixing materials and waiting for them to set, cleaning up the mess from the impressions, disinfecting the impressions, and shipping the impressions to a laboratory. The CEREC and E4D devices can be combined with in-office design and milling; whereas, the iTero and Lava COS devices are reserved for image acquisition only. Each system uses a different method to acquire the images. In-office milling allows same-day restorations [2, 16]. The first system introduced was the CEREC 1 in 1986. The CEREC 1, 2 (1994) and 3 (2000) systems (Sirona Dental) have all used a still camera to take multiple pictures that are stitched together with software. The E4D (D4D TECH) takes several images, using a red light laser to reflect off of the tooth structure and only requires the use of powder in some limited circumstances. The application of powder to the tooth is quick and simple, taking only seconds, and the powder is easily removed afterwards with air and water. The iTero system uses a camera that takes several views (stills), and uses a strobe effect as well as a small probe that touches the tooth to give an optimal focal length; this system does not require the use of powder. The LAVA Chairside Oral Scanner (LAVA COS, 3M ESPE) takes a completely different approach using a continuous video stream of the teeth. CEREC and LAVA currently require the use of powder for the cameras to register the topography [17].

Laboratory production

This variant of production is the equivalent to the traditional working sequence production between the dentist and the laboratory. The dentist sends the impression to laboratory where a master cast is fabricated first. The remaining CAD/CAM production steps are carried out completely in the laboratory. With the assistance of a scanner, three-dimensional data are produced on the basis of the master die. These data are processed by means of dental design software. After the CAD-process the data will be sent to a special milling device that produces the real geometry in the dental laboratory. Finally the exact fit of the framework can be evaluated and, if necessary, corrected on the basis of the master cast [12].

A major advantage of using CAD/CAM systems in the laboratory is that the final restoration can look exactly like the provisional. CAD/CAM systems also shorten the learning curve for new dental technicians, although a dental technician still finishes each restoration by hand. CAD/CAM technology does not replace the need for skilled dental laboratory technicians [2].

Centralized production

The third option of computer-assisted production of dental prostheses is centralized production in a milling centre. In this variation, it is possible for 'satellite scanners' in the dental laboratory to be connected with a production centre via the Internet. Data sets produced in the dental laboratory are sent to the production centre for the restorations to be produced with a CAD/CAM device. Finally, the production centre sends the prosthesis to the responsible laboratory. Thus, production steps 1 and 2 take place in the dental laboratory, while the third step takes place in the centre [12]. This production model minimizes the cost to the laboratory and has the potential to improve fabrication efficiencies [18].

CAD/CAM in different fields of prosthetic dentistry

CAD/CAM in removable prosthodontics

The fabrication of complete dentures using a computer-aided design/computer-aided manufacturing (CAD/CAM) system has the potential to simplify the above process and resolve the associated problems. In recent years, CAD/CAM systems have been successfully introduced into restorative dentistry and maxillofacial technology. Moreover, they have been applied to removable prostheses [19]. Regarding the removable partial denture, the framework design is drawn on the working cast and then scanned using a laboratory scanner. The framework is always fabricated by printing a photo polymeric framework and then cast with chromium cobalt, or the framework can be printed directly from chromium cobalt through Direct Metal Laser Sintering [15].

CAD/CAM technology in implant prosthodontics

CAD/CAM allows simplified production of precise and durable implant components. The precision of fit has been proven in several laboratory experiments and has been attributed to the design of implants. Milling also facilitates component fabrication from durable and aesthetic materials. The CAD component virtually designs the 3D contour of the final implant component. The CAM system produces the actual implant component according to the virtual design. In implant dentistry, the implant abutments and frameworks are produced by milling at a central production facility. Examples of these systems are Procera (Nobel Biocare), Etkon (Straumann), CAMStructure (Biomet 3i), and Atlantis (Astra Tech). Custom CAD/CAM abutments combine most of the advantages of stock and cast custom abutments [20].

CAD/CAM in manufacturing surgical guides

The conventional surgical guides were used as a control for the manual check of the deviation of the implant axis. The direct transfer of the digital planning data allows the fabrication of surgical guides in an external center without the need of physical transport, which reduces the logistic effort and expense of the central fabrication of surgical guides [21]. Bibb *et al.* described the fabrication of stainless steel surgical guides for the placement of dental implants for prosthetic retention using SLM technology. It was first reported for the manufacture of custom-fitting surgical guides [22].

CAD/CAM technology in maxillofacial prosthodontics

CAD/CAM is widely used for the fabrication of maxillofacial prostheses, extraoral radiation devices, individual respiratory masks and facial protection devices etc. Three dimensional surfaces imaging is done by using CAD software. This 3-D surface image aids in the fabrication of resin model with Lithographic technique and then wax pattern is made. Of this completed wax pattern, once again computer assisted three dimensional imaging is done. Data is entered in computer and prosthesis is milled by computer aided milling machine. Thus, a silicone maxillofacial prosthesis is fabricated using CAD/CAM technology [1].

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