Review Article

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Digital Dentistry: The future of Dentistry

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ABSTRACT

Background: Dentistry has evolved since 1971 into the digital world of image capture, computer design and the creation of dental restorations through robotics. Computer aided technologies provide more precise and systematic modeling and could therefore reduce the burdensome steps of both the chairside and laboratory work, saving the vital time. The application of CAD CAM and rapid prototyping technologies have increased considerably in the field of prosthodontics in the recent years. CAD CAM has recently seen successful applications in various medical fields such as fabrication of implant surgical guides, maxillofacial prosthetics, wax patterns for dental prosthesis, zirconia prosthesis, molds for metal casting and finally complete dentures by its subtractive methods.

Keywords: Rapid prototype, cad-cam, cerec, lava, prosthesis.

INTRODUCTION

Traditional methods for the production of indirect restorations usually include impression making, die or model making and final manufacture. Inaccuracies can occur at any stage, and if introduced early on, may have an exaggerated effect on the final restoration. CAD/CAM is an acronym for Computer-Aided Designing and Computer-assisted Manufacturing. Over the past 25 years, CAD/CAM technology has become extremely popular. It is widely being used, in dental laboratories and in dental offices, to design and machine various restorations viz. veneers, inlays, onlays, crowns, fixed dental prostheses, implant abutments, cast removable partial dentures and even full-mouth rehabilitation. The advent of interactive computer graphics, computer aided design and computer aided manufacturing laid the ground work for a revolution in engineering and dentistry. CAD-CAM provides tools to automate design and production, improving productivity and quality. Dental CAD-CAM systems are being developed to bring this automation to produce dental restorations.

Restoration design, whether with the lost wax casting technique or a CAD-CAM system, has three functional components: Data acquisition, restoration design and restoration fabrication. Data acquisition (all the steps currently involved in making impression and, with some systems, creating models and dies) can be automated. Design, currently the waxing process, is replaced with computer.

HISTORY

CAD- CAM technologies were introduced to dental profession in 1971[1]. In 1979, Heitlinger and Rodder[1], followed by Moermann and Brandestini[1] in 1980, began to share this approach. The former researchers milled the equivalent of the stone models used by a dental technician to make the crown, inlay, pontic, while the latter team took single picture and milled only the internal surface of

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the inlay. During the next 5 years, little was done. The first crown was publically milled and installed in a mouth without any laboratory involvement in 1985[1]. Though 1985 was a decisive year for computer aided dentistry, there was still a long way to go. Two new names appeared at this time, one Aoki's team in Japan and second Diane Rekow at University of Minnesota. Dr. Rekow chose a photogrammetric method to acquire the third dimension and used the principle of theoretical tooth.

Advantages:

- One visit procedure.
- No mercury involved.
- Looks great- available in multiple shades to better match natural tooth color.
- Saves time.
- Great longevity.[2]
- Their use minimizes cross infection.

Disadvantages:

- High cost.
- Technique sensitive.
- High clinical skill level needed.
- Requires removal of considerable sound tooth structure.
- High and unpredictable fracture rates.
- Excessive wear of opposing tooth may occur if opposing surface is not properly glazed or polished.

Uses: (General Uses)

a) All CAD-CAM systems permit the production of restoration at the chairside.
b) Eliminate potential inaccuracies associated with the traditional, multistage production of indirect restoration.

USES IN PROSTHODONTICS

CAD/CAM technology in fixed prosthodontics

CEREC in Lab system - The tooth preparation die is secured in the scanning platform and data is captured with a non-contact laser. A Ceramic block (ingot) is placed in the milling chamber. Two milling diamonds create the precise restoration. Porcelain build-up is done which results in an aesthetically pleasing restoration. Then the fit is confirmed in the patient's mouth and required adjustments are done.

CAD/CAM technology in maxillofacial prosthodontics [3, 4]

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.

CAD/CAM technology in removable partial denture prostheses

Fabrication of cast partial dentures can be done using Co-Cr Alloys or commercially pure Titanium and Ti-6Al-4V.

Alloy by utilizing CAD-CAM technologies. William *et al* have demonstrated a method of fabrication of removable partial denture framework design using CAD/CAM technologies. Using CAD/CAM software the removable partial denture framework design is built on a three-dimensional scan of the patient's cast. [5, 6]

CAD/CAM technology in implant prosthodontics

Computer usage in implant placement (Navigational technique) has increased in the past decade. Recently with the use of CAD/CAM application patient-specific abutments can be fabricated. These CAD/CAM fabricated custom abutments are designed by computer and manufactured by computer operated machines for obtaining unsurpassed accuracy and precision. As they are milled from medical-grade Titanium, they have superior biocompatibility and best possible integration with implant fixture.

The CAD/CAM fabricated custom abutments carries advantages like: - precision, milled from titanium, ideal coronal preparation, correct path of insertion, perfect emergence profile, 6° angled

implant axis, shaped like a natural tooth and reduced chair time. Computerized designing of abutment is done and primary abutment is fabricated from commercially pure titanium via computerized-milling technique. Another duplicate abutment is milled, which is functionally identical to primary abutment, thus reducing chair time.[7]

CAD/CAM technology in fabrication of surgical guides for implant placement

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.[8]

COMMERCIALLY AVAILABLE SYSTEMS

1. The **CEREC system**[9,10,11], Invented by Mormann and Brandestini and developed by Siemens, Cerec was introduced to the dental profession in 1987. It is the most widely investigated and reported CAD/CAM system to data. The main features comprise an intra-oral camera, an image-processing unit linked to a viewing screen and a micro milling machine.
2. The **Duret system** produced by Sopha (Lyon, France)[9,10] consists of three discrete units: a camera module for data acquisition, the CAD module to design the restoration and the milling module.
3. The **DUX system**, also known as the Titan system (DSC Dental, Allschwill, Switzerland) consists of a miniature contact digitizer, a central computer and a milling unit[9]. The digitizer consists of a table that shifts a die or model beneath a contact stylus. The central computer includes limited CAD capabilities.
4. The **Celay system** (Mikrona Technologic, Spreitenbach, Switzerland) is a very small unit that consists of a contact digitizer that "reads" the shape of an acrylic inlay and directly transfers that shape to a miniature milling machine.[9,10] The system is similar to a key copying or pantograph machine.
5. The **Procera[9] system** (Nobelpharma, Inc., Goteborg, Sweden) is a copying and fabrication system using a pantograph and electric discharge machining. The shape of the die and the wax pattern of the restoration are "read" by a pantograph stylus that transmits these shapes to a milling machine to produce electrodes in these shapes. These electrodes are used to produce a restoration with EDM (electric discharge machining).
6. The **DentiCAD system**[9,10] (BEGO, Bermen, Germany, and DentiCAD USA, Waltham, Mass) system consists of a miniature robot arm digitizer, CAD-CAM software with an expert system for fully automated design and a milling machine. The robot arm digitizer can be used intra orally or on traditional models and dies. The CAD-CAM software and expert system reside in a personal computer. The milling machine is directly controlled by the computer.
7. The **CICERO**[12] The Cicero (Computer-integrated crown reconstruction) system makes use of optical scanning, near net-shaped metal and ceramic sintering and computer-aided fabrication techniques.

Manufacturing details:

Information is digitized from a gypsum cast, using a fast laserstripe scanning method. Up to 100,000 surface points may be recorded per minute. An appropriate tooth is selected from a collection of generic forms of theoretical teeth in the programme's library. Mesial and distal contacts of the proposed restoration are outlined by the operator on a video screen and the margin of the new crown adjusted to the preparation. Working, balancing and protrusive pathways for the new restoration are also computed at this stage. After interior and exterior tooth surfaces have been defined, the interfaces between cement and metal, and between dentine and incisal porcelains, are delineated. Built into the software is accommodation for the overall thickness of cement and metal substructure.

8) CEREC: Invented by Mormann and Brandestini and developed by Siemens, Cerec was introduced to the dental profession in 1987. It is the most widely investigated and reported CAD/CAM system to data. The main features comprise an intra-oral camera, an image-processing unit linked to a viewing screen and a micro milling machine. (Computer Integrated crown reconstruction) system is a registered trademark of Cicero Dental System B.V. (Hoorn, The Netherlands).

9) The COMET[13] system (Coordinate Measuring Technique, steinbichler optotechnique GmbH, Neubeuern, Germany) allows the generation of a three-dimensional data record for each superstructure, with or without the use of a wax pattern. The system uses a combination of strip projection methods with triangulation, enabling measurement of the coordinates of all measurement points recorded by a charge-coupler device (CCD) camera not only with high precision but also at high speeds.

Comparison of System Capabilities

Perhaps one greatest difference among the systems is the type of restoration that can be produced. The CEREC and Celay systems can produce only inlays and a few onlays. The new CEREC system (CEREC MK11[12]) can mill single tooth restorations in the form of inlays, onlays, crowns and veneers. The DUX system produces copings while Procera[13,14] system produces copings and all ceramic crowns. They have sufficient CAD capabilities to design the occlusal surface of the restoration. The Duret and DentiCAD systems can produce inlays, copings, crowns & bridges. The CICERO [10, 11] system was developed for the production of inlays, onlays, crowns and fixed partial dentures.

9) The E4D Dentist System

The E4D Dentist system, which made its debut in 2008, is presently the only other system besides CEREC that permits same-day in-office restorations.15 Dentists can purchase the design center and laser scanner alone, or also purchase the milling unit. This system includes a laser scanner, called the IntraOral Digitizer, along with a design center and milling unit. The scanner is small, so patients do not need to open their mouth as wide (Fig.1). The E4D system requires the use of powder in some but not all cases. To use the system, the restoration site is prepared as it is for a traditional impression. The scanner is placed near the target tooth, and has 2 rubber feet that hold it a specific distance from the area being scanned.

Fig 1: E4D System.

10) **The Cadent iTero**

Cadent introduced iTero in 2007 as the first digital impression system for conventionally manufactured crowns and bridges. Unlike the other 3 digital impression systems, which acquire images using triangulation, iTero employs parallel confocal imaging.[16] Specifically, the device projects 100,000 parallel beams of red laser light at the teeth and transforms the reflected light into digital data through the use of analog-to-digital converters.[17] This technology allows scans to be taken without coating the teeth in powder. The absence of powder means that the scanner can be rested directly on the teeth during scanning. One disadvantage is that the scanner head is larger than those of the other 3 scanners discussed here.

11) The Lava Chairside Oral Scanner

The Lava Chairside Oral Scanner (COS) was launched in February 2008.[15] The system includes a mobile cart, a touch screen display, and a scanner with a camera at the end (Fig.2) The camera, which contains 192 LEDs and 22 lens systems, employs active wavefront sampling to capture images at video rate. After preparing the tooth and retracting the gingival tissue, the dentist dries the arch and gives it a light dusting of titanium dioxide powder. Just enough powder is used to permit the scanner to identify reference points. The Lava COS can be used to make any type of crown or bridge, not just Lava crowns and bridges.[15]

Fig 2: LAVA COS System.

12) CEREC AC

CEREC AC powered by BlueCam (Sirona, Charlotte, NC, USA) was introduced in 2009,[18] also had the ability to take half-arch or full-arch impressions and create crowns, veneers, and bridges. This system employs intense blue light from blue light-emitting diodes (LEDs). The camera projects blue light onto the teeth, which reflects it back at a slightly different angle. This method of visualization is referred to as active triangulation. To use the system, the entire tooth preparation to be scanned is coated with a layer of special titanium dioxide powder, which makes translucent areas of the teeth opaque and permits the camera to register all of the tissues. Several optical impressions are then taken from an occlusal orientation, being sure to obtain images of the tooth to be restored as well as the adjacent and opposing teeth. The scanner is able to focus automatically.

Materials Available

Various materials are available for fabricating CAD-CAM restorations. Many systems, however, can use only few. The two most widely used ceramic materials are machinable glass ceramic (Dicor, Dentsply International, York, Pa) and Vita Porcelain (Vita Zahn Fabrik, Bad Sachingen, Germany). Titanium is another popular choice. It is preferred material for the DUX and Procera systems. Because the Procera system fabricates restorations with Electric Discharge Machining (EDM), only electrically conductive materials can be fabricated. Duret and DentiCAD systems offer a broader range of material choice - indenting machinable ceramics, metals (including titanium), and composites. The Duret system also offers an organoceramic material (Aristee, Spad Dijon, France)

DENTAL CAD-CAM SYSTEM COMPARISON

	CEREC	DURET	DUX	CELAY	PROCERA	DENTICAD
Data acquisition Fabrication	Optical Milling & hand finish	Optical Milling	Mechanical impression, milling	Mechanical-direct acrylic Milling	Mechanical waxup EDM	Mechanical-direct Milling
Restoration type	Inlay, Onlay, Crown	Crown, Inlay coping	Coping	Inlay	Crown	Crown, Coping
Material	Dicor, Vita	Dicor, Aristee	Titanium	Ceramic	Titanium	Metal, ceramic composite.
Design automation	Moderate	Moderate	Low	Low	Low	High
Data acquisition	<5 minutes	<5 minutes	<15 minutes + model	15 minutes + model	20 min + model + wax-up	<5 minute
Restoration design	< 10 minutes	50 minutes	<5 minutes	Wax up	Wax up	<3 minute
Fabrication time	<15 minutes + grind in occlusion	30 minutes	30 minutes	5 minutes	90 minutes	<20 minutes
Total time: preparation seated in patient	90 minutes	80 minutes	50 minutes + model	20 minutes + wax up	110 minutes + wax up + model	< 30 minutes
Learning curve-New Technologies	Optical impression, CAD, milling	Optical impression, CAD, milling	Mechanical digitizer Milling	Milling	EDM, Milling, digitizer.	Mechanical digitizer milling.
Initial system cost	Mid	High	Low	Low	High	Mid-High
Operator	Clinician	Clinician	Clinician or technician	Clinician	Clinician, technician	No special expertise

STAGES IN PROSTHESES FABRICATION[19]

There are various stages in fabrication of the prostheses with CAD/CAM technology.

1. Computer surface digitization
2. Computer-aided designing
3. Computer assisted manufacturing

The first stage is the Computer surface digitization. This technique can be broadly divided into two categories:

1. Mechanical scanning devices.
2. Optical scanning devices.

Optical camera, LASER surface scanning device, three dimensional (3-D) scanning device (digitizer), photogrammetry, Moiré fringe displacement, computed tomography (CT-Scan), magnetic resonance imaging (MRI), 3-D ultrasonography etc. are some of the technologies used for computer surface digitization.

The next stage in CAD/CAM is Computer-aided designing (CAD). Once the 3-D image is captured through any of the computer surface digitization techniques, 3-D image processing is done and the digitized data is entered in the computer. Finally, curve smoothening, data reduction and blocking of undercuts can be done at this stage. Designing of the restoration is done using CAD software, which in turn sends commands to the CAM unit, for fabricating the restoration.

Third and the final stage is Computer-aided manufacturing (CAM). In this stage the milling is done with computerized electrically driven diamond disks or burs which cut the restoration from ingots. This process is commonly known as "subtractive method".

SUMMARY

With the advent of computer graphics, the CAD-CAM system has developed from a simple unit to a small complex unit for electronically designing and milling ceramic restorations. It is now possible to provide the equivalent of a cast restoration with a single appointment. Several systems are under development, each providing different characteristics and advantages. CAD-CAM restorations are already a part of dentistry and its future evolution could be spectacular considering its numerous possibilities. Advances in CAD/CAM technology have catalyzed the developments of aesthetic all ceramic restorations with superior biomechanical properties. Although none of the materials exhibit ideal clinical properties for universal applications, intense research efforts are under way to promote the strength, aesthetics, accuracy and an ability to reliably bond to dental substrates. Other CAM methods which are "additive", for example rapid prototyping, selective laser sintering & 3-D printing are also evolving gradually.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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