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CAD/CAM in Restorative Dentistry: A Review

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ABSTRACT

Advancements in computer systems and technologies have revolutionized the field of dentistry as well. These advancements can be seen with the introduction and evolution of CAD/CAM systems. The demand for such systems has grown dramatically over the past decade and a large variety of different CAD/CAM systems have been developed and marketed. The popularity of these systems can be attributed to their efficiency of designing, manufacturing and precision.

Introduction

From its inception to now dentistry has covered great milestones in terms of invention, innovation and precision which aim to provide us with better working conditions and increased comfort for both dentists and patients. To add to the list of remarkable advancements is CAD/CAM. Computer-aided design / computer-aided manufacturing technology for dentistry is allowing us to provide even better care for patients.

CAD – Computer Aided Designing is the use of computer systems in the design and development of a product. CAM – Computer Aided Machining is the use of a computer system to operate machine tools which allows the shaping of materials to form structures and devices.

History-How it All Began

CAD/CAM was first introduced in the 1960's in aircraft and automotive industry[1]. In dentistry, the major developments of dental CAD/CAM systems occurred in the 1970s. There were three pioneers in particular who contributed to the development of the current dental CAD/CAM systems. Dr. Duretin1971 introduced First dental CAD/CAM &First dental CAD-CAM restoration in 1983[2]. Dr. Mörmann 1985 made First commercial dental CAD CAM system – CEREC[3]. The emergence of this system was really innovative because it allowed same-day ceramic restorations. Dr. Anderssonin Mid 1980'sintroducedProcera system[4].

Evolution of CAD/CAM systems

1985 - The first CAD/ CAM crown was publicly milled and installed in a mouth without any laboratory involvement.

1986 - The first generation CEREC 1 (Siemens Corp) was introduced.

1994 - The second generation CEREC 2 (Siemens Corp) was presented.

1999 - The third generation Cerec 3 (Sirona, Benheim, Germany.

2003 - Cerec 3D (Sirona, Benheim, Germany).

Potentials of CAD/CAM system

Make restorations easier, faster and more accurate. Ensure adequate strength of the restorations. Create restorations with natural appearance[1].

Fabrication of restoration, whether with conventional method or highly advanced technique has 3 functional components[5]:

- Data acquisition
- Restoration fabrication
- Restoration design

In conventional method data acquisition is made by impression making, obtaining a cast, restoration design by wax pattern and fabrication by investing and casting. On the contrary, in high technology, data acquisition is done digitally, the design is made on the computer and fabrication is done by computer assisted manufacturing. CAD/CAM system has two major components – CAD and CAM. The CAD unit in which optical impression is taken and designing of the restoration is done. Transfer of design is made to CAM which has machining unit.

I. CAD
- Digital impression
- Designing of the restoration

II. CAM
- Machining unit

Computer aided design

a) Digital impression (Data acquisition / Computerized surface digitization)

Dentists have tried to perfect the ultimate way to reproduce the intraoral condition, extra orally since the early days of the profession: from copper-bands and compound, to rubber base, to reversible hydrocolloid, to vinyl polysiloxane (VPS), and now to digital capture. Every few decades, the impression protocols have undergone a significant shift. Nowadays the shift from physical impressions to digital impressions have taken place.

Basically, there are two different scanning possibilities[6]:

- Optical scanners – direct / indirect
- Mechanical scanners

Optical scanners

Here, the source of light (e.g. laser) and the receptor unit are at a definite angle in their relationship to one another. Through this angle the computer can calculate a three-dimensional data set from the image of the receptor unit. Either white light projections or a laser beam can serve as a source of illumination. Examples of optical scanners on the dental market: Lava scans ST (3M ESPE, white light projections), Everest scan (kavo, white light projections)[6].

Drawbacks–complicated mechanics, very expensive and long processing time.

They can be direct or indirect.

Direct and indirect scanner – In direct scanner image is obtained by directly scanning inside the patient's mouth while in indirect scanner data acquisition is done by scanning the impression or cast.

Mechanical scanner[6]

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.

Among the various methods of surface scanning–optical scanners have been proven the most suitable.

b) Restoration design (4. Joerg R Strub, E Dianne Rekow, Siegbert Witkowski. Computer aided design and fabrication of dental restorations. *J Am Dent Assoc* 2006; 137 (9): 1289-1296)

After recording the impression with scanner a 3 - dimensional image is generated, then the operator enters data and confirms the features of the preparation. The CAD software which designs the restoration has following features:

- Insertion pathway - CAD program proposes an optimal insertion path to provide minimal undercuts.
- Block-out – just about all CAD/CAM program today blocks out undercut with a click of a button.
- Margin identification – some program auto-detects the margin while others may require the user to click on the margin and the software detects the rest.
- The margin reinforcement – margin being at the edge of the coping and with minimal thickness is most prone to chipping or damage during milling. Hence, to improve viability additional thickness is added to the margin during designing.
- Virtual articulator – allows programmable protrusive & excursive movements to enable technicians to seek occlusal interferences & design accordingly.
- Libraries – CAD software program support library teeth from which a technician may choose when designing full contour restorations.

The data of the construction can be stored in various data formats. The basis is often standard transformation language (STL) data[7]. When the design of the restoration is completed, CAD software transforms the virtual model into a specific set of commands for fabrication.

c) Restoration fabrication

Fabrication of restoration in CAD/CAM system is via computer and can be broadly be done by a subtractive or additive method. Additive manufacturing uses images from a digital file to create an object by laying down successive layers of a chosen material. Subtractive manufacturing uses images from a digital file to create an object by machining (cutting/milling) to physically remove material and achieve the desired geometry.

Computer aided manufacturing

CAD CAM generated restoration can either be fabricated through subtractive technique or additive method. Computer aided manufacturing.

CAM uses computer generated path to shape a restoration. Early systems relied almost exclusively on cutting the restoration from a prefabricated block with the use of burs, diamonds or diamond disks.

a. Subtractive technique

After the design of the restorations is completed, data for processing is calculated automatically. Processing devices are distinguished by means of the number of milling axes[8]. (See figure 1.)

Copy milling

Different possibilities of working axis: 3 spatial direction X, Y and Z (3axis milling devices); 3 spatial directions X, Y, Z and tension bridge A (4 axis milling device); 3 spatial directions X, Y, Z, tension bridge A and milling spindle B (5 axis milling device)[6].

Copy milling includes fabrication of a prototype (pro-inlay or crown) usually via impression making and model preparation. Based on the model, a replica of inlay/crown is made and fixed in the copying device and transferred 1:1 into the chosen material such as ceramic[9].

Spark erosion

It may be defined as a metal removal process using a series of sparks to erode material from a workpiece in a liquid medium under carefully controlled conditions[10].

b. Additive technique / rapid prototyping

Rapid prototyping techniques

- Stereolithography
- Selective Laser Sintering (SLS)
- 3-D Printing
- Fused Deposition Modeling (FDM)
- Solid Ground Curing
- Laminated Object Manufacturing (LOM)

➢ Stereolithography

Stereolithography (SLA) is the most widely used rapid prototyping technology. It is the technique for creating 3 dimensional objects in which a computer controlled moving laser beam is used to build up the required structure layer by layer[11]. (See figure 2.)

➢ Selective laser sintering (SLS)

Selective laser sintering (SLS) is an additive manufacturing technique used for the low volume production of prototype models and functional components.

Starts by converting the CAD data in series of layer. These layers are transferred to the additive SLS machine which begins to lay the first layer of powder. As the laser scans the surface, the material is heated and fuse together. Once the single layer formation is completed, the powder bed is lowered and the next layer of powder is rolled out smooth & subjected to laser. Hence layer by layer formation of the object takes place[12].

➢ 3-D printing

It is similar to operating an inkjet printer, the machine builds wax patterns of frameworks and full crowns. The wax pattern subsequently is cast or pressed manually[12].

Common CAD/CAM systems in dental practice

Based on their production methods[6]

- In office system / chairside
- CAD / CAMS–Dental laboratory models
- CAD/CAM for outsourcing dental lab work using networks.

Chairside production

All components of the CAD/CAM system located in the dental operatory. Fabrication of dental restorations can thus take place at chairside without any laboratory procedure. Saves time and offers the patient restorations at one appointment. EG – CEREC, E4D.

Laboratory production

The dentist sends the impression to the laboratory where a master cast is fabricated first. The remaining CAD/CAM production steps are carried out completely in the laboratory. Eg: cerecinlab.

Centralized production

The third option of computer-assisted production of dental prosthesis is centralized production in a milling center. Data sets produced in the dental laboratory are sent to the production center for the restorations to be produced with a CAD/CAM device. Finally, the production center sends the prosthesis to the responsible laboratory. EG: Procera introduced in 1994 is the first system which provided outsourced fabrication using a network connection.

Clinical application

- Veneers, crowns and bridges
- Full mouth rehabilitation
- Implant abutment
- Maxillofacial prosthesis
- Cast partial dentures
- Complete dentures
- Orthodontic appliances

Advantages of CAD/CAM system

- One-visit restorative procedure with chairside
- No impression making
- Reduced potential for tooth sensitization
- No model or die pouring
- No laboratory costs
- Less opportunity for error
- Aids preparation, visualization

Disadvantages of CAD/CAM system

- Higher production required to cover the capital investment
- High learning curve
- Depending on the material and patient, customization may be required.

Conclusion

Using CAD/CAM technology in the dental office and laboratory may have seemed like science fiction 20 years ago, but today it is a reality. Dental CAD/CAM technology is successful today because of the vision of many great pioneers. As Duret, concluded in his article in 1991, "the systems will continue to improve in versatility, accuracy, and cost effectiveness, and will be a part of routine dental practice from the beginning of the 21st century.

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- 3 – axis devices
- 4 – axis devices
- 5 – axis devices

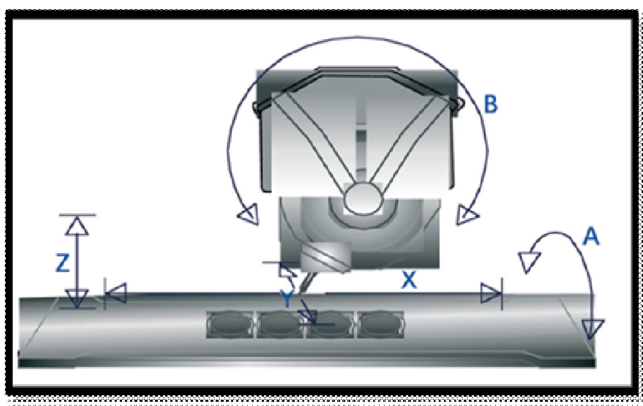

Figure 1. Different possibilities of working axis

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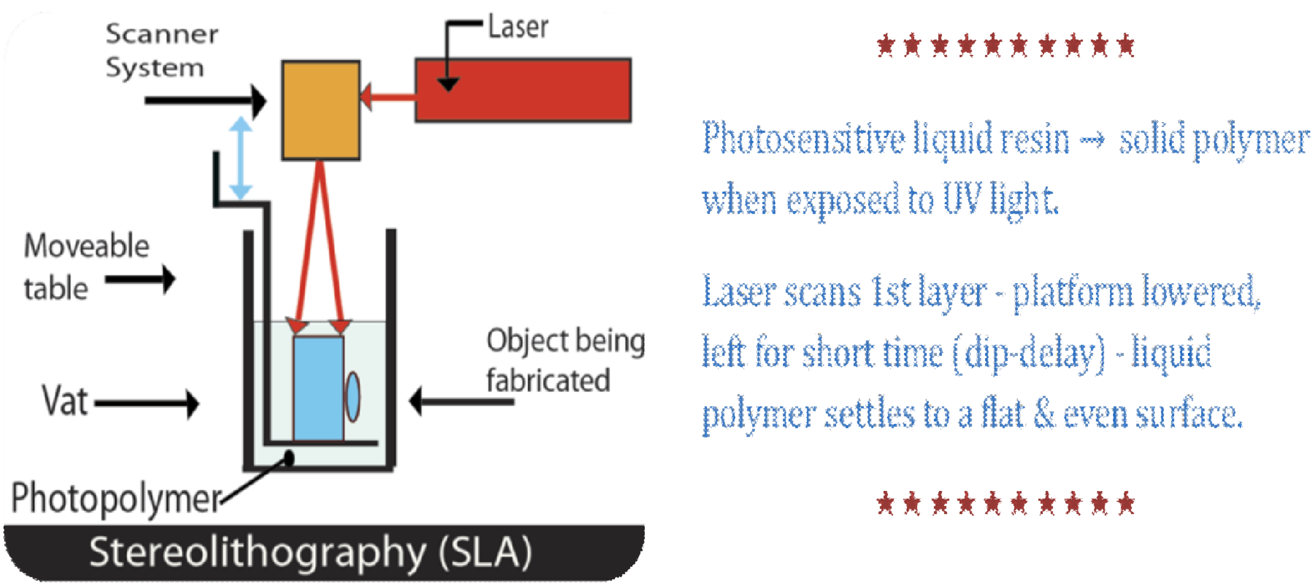

Figure 2. Stereolithography (SLA)

(http://www.martello.co.uk)