CAD-CAM – A review by the Restorative Dentist.

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Abstract

Computer-aided design and computer-aided manufacturing (CAD/CAM) dentistry is an evolutionary change for dentistry. CAD/CAM is a field of dentistry which is designed to create accurate and efficient dental designs. CAD/CAM being a paramount in technological advancement, being one of the highly performative dental lab technologies that have been introduced. This article provides an overview of various CAD/CAM systems.

Key words: Computer-aided design and computer-aided manufacturing, Restorative dentist, scanner, Cerec.

Introduction

The introduction of the dental CAD/CAM Systems began in the 1970's with Duret in France, Altschueler in the USA and Mormann and Brandestini in Switzerland.[1,2] There were three Pioneers in particular who contributed to the development of the current CAD/ CAM systems.[3]

Dental CAD/CAM was developed in the field of dentistry by Dr. Duret in the year 1971. Hereafter, he began to fabricate crowns which had the functional shape of the occlusal surface with the help of a series of systems starting with an optical impression of the abutment tooth, designing an optimal crown with functional movement, and milling a crown using a numerically guided milling machine. Furthermore, he developed the Sopha System, which had an impact on the later development of the dental CAD/CAM systems globally.[3]

Subsequently, Dr. Moermann developed the CEREC system in 1980 with an engineer Marco Brandestini. He attempted to use new technology in a dental office clinically at the chair side of patients.

He directly measured the prepared cavity with an intra-oral camera, which was followed by the design and carving of an inlay from a ceramic block using a compact machine set at chair-side. The emergence of this system was ingenious as it allowed chair-side ceramic restorations. When this system was announced, it rapidly spread the term CAD/CAM to the dental profession.[3] In 1985, CEREC 1 was marketed by Siemens in Europe. In 1987 the first clinical trials took place. And in 1989 the CEREC System was introduced to the United States. Since then, the system has evolved through a series of hardware and software upgrades to reach the present form, the 3D CEREC Systems.[4,5]

One the three pioneers is Dr. Andersson who developed the Procera system. In the year 1980, Nickel-Chromium alloys were used as an alternative for gold alloys. As at that time the gold price was unduly expensive. A transition to allergy-free titanium was initiated in Northern Europe, due to complications caused by metal allergies.

Dr. Andersson aimed to fabricate titanium copings by spark erosion, as accurate casting of titanium was difficult to fabricate during that time. He introduced CAD/CAM technology into the process of composite veneered restorations. The requisition of CAD/CAM was a specialized procedure which was as a part of a total processing system, that later emergedas a processing center tessellated with satellite digitizers globally for creation of all-ceramic frameworks. Currently such networked production systems are being launched by a number of company's worldwide.[3] In 1983, at Ganaciene Conference (France), the first dental CAD/CAM prototype was presented and in 1985 the first crown was publicly milled and placed in a mouth without any laboratory involvement.

Dental CAD/CAM

Dental CAD/CAM is the system in which the model of a prepared tooth is scanned. The acquired data is then used to create the coping design (CAD) which in turn generate a cutting path for fabricating the coping (CAM).

Computer Aided Design (CAD) and Computer Aided Manufacture (CAM) in restorative dentistry can be used to:

- Reduce production time for copings and frameworks; increasing overall productivity.
- Introduce consistent and measurable accuracy.
- Provide evidence of product quality.

CAD/CAM Components

1. Scanner

It is a data collection tools that measure three dimensional jaw and tooth structures and simultaneously transform them into digital data sets. Basically there are two different Scanning possibilities:

a) optical scanners
b) Mechanical scanners.

a) Optical scanners

The basis of the scanner is to accumulate the three-dimensional structures in a 'triangulation procedure'. Here, the source of light (e.g laser) and the receptor unit are in a precise angle in association to one another. Through this angle the computer can calculate a three-dimensional data set from the image on the receptor unit.[6] Moreover, white light projections or a laser beam is used as a source of illumination. The following are the examples of optical scanners on the dental market:

Fig 1: White light projector pattern during the scanning procedure by an optical scanner

- Lava Scan ST (3M ESPE, white light projections)
- Everest Scan (KaVo, white light projections)
- es1 (etkon, laser beam).

b) Mechanical scanner

Here the master cast is read mechanically line-by-line by ruby ball and the three-dimensional structure measured. The Procera Scanner from Nobel Biocare (Göteborg) is the one of the example for mechanical scanners in dentistry. 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.[7,8] The drawbacks of this data measurement technique are to be seen in the inordinately complicated mechanics, which make the apparatus extravagant with lengthy processing time in comparison to optical systems.

2. Design software

Special software is provided by the manufacturers for the design of various kinds of dental restorations. With such software, crown and fixed partial dentures (FPD) frameworks can be constructed on one hand; while on the other hand, some systems also offer the opportunity to

Fig 2: Mechanical scanner

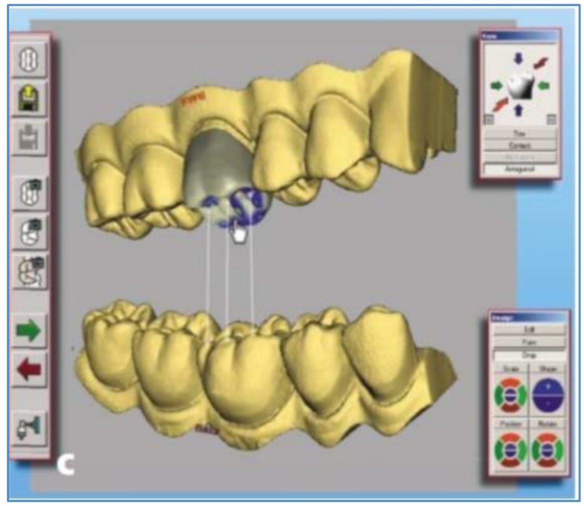

Fig 3: The evolution of CEREC software (Sirona Dental Systems GmbH, Bensheim, Germany)

design full anatomical crowns, partial crowns, inlays, telescopic primary crowns, along with adhesive FPDs and inlay retained FPDs. The software of CAD/CAM systems currently available on the market is continually being upgraded. 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. The systems available are individualized based on the software development. Moreover, many systems signifies an indication spectrum that is extensive, while other systems place emphasis on automated use and user-friendliness.

3. Processing devices

The planning data produced with the CAD software are transformed into milling strips for the CAM-processing and finally loaded into the milling device. Processing devices are illustrated into following milling axes:

a) 3-axis devices
b) 4-axis devices
c) 5-axis devices.

a) 3-axis milling devices

3-axis milling device has degrees of movement in the three spatial directions. Thus, the mill path points are uniquely defined by the X -, Y -, and Z – values. The calculation investment is therefore minimal. A milling of subsections, axis divergences and convergences, however, is not possible. This demands a virtual blocking in such areas. All 3-axis devices used in the dental area can also turn the component by 180° in the course of processing the inside and the outside. The advantages of these milling devices are short milling times and simplified control by means of the three axes. As a result, such milling devices are usually less costly than those with a higher number of axes. Example: inLab (Sirona), Lava (3M ESPE), Cercon brain.

b) 4-axis milling devices

The 4-axis milling devicesin addition to the three spatial axes X, Y and Z axis the component can also be rotated boundlessly variably i.e. rotation around the X-axis (A-axis).Thus, it is possible to regulate bridge constructions with a large vertical height displacement into the usual mould dimensions hence preserve material and decreases milling time. Example: Zeno (Wieland-Imes).

c) 5-axis milling devices

With a 5-axis milling device there is also, in addition to the three spatial dimensions and the rotatable tension bridge (4th axis), the possibility of rotating the milling spindle (5th axis). This enables the milling of complex geometries with subsections, such as in, lower jaw FPDs on converging abutment teeth (end molar tipped towards the medial plane), or also crown and FPD substructures that, as a result of anatomically reduced formation, demonstrate converging areas in the exterior of the frame. Example: Everest Engine (KaVo).

Example in the Production Centre: HSC Milling Device (etkon).

The standard of the restoration does not significantly increase with the number of processing axes. The quality relies more on the result of the digitalisation, data processing and production process.

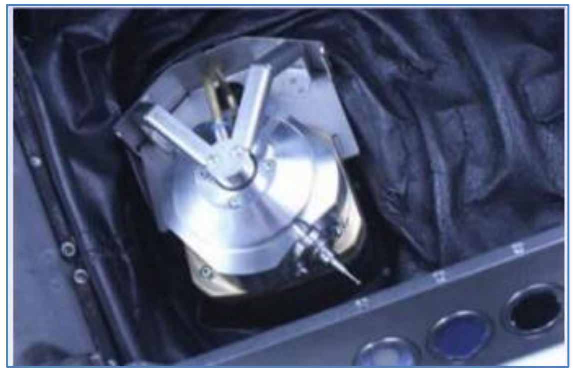

Fig 4: Axis milling device

Fig 5: Axis milling device

Materials for CAD/CAM processing

A) Metals

Currently chrome cobalt alloys, titanium and titanium alloys are processed using dental milling devices. The milling of precious metal alloys has been shown to be of no economic interest, due to the high metal attrition and the high material costs.

Examples: coron (etkon: non-precious metal alloy), Everest Bio T-Blank (KaVo, pure titanium).

B) Resin materials

Resin materials can be used for the milling of lost wax frames for casting technology; and also it is possible to use resin materials as crown and FPD frameworks for persisting, transitional or complete anatomical long term transitional prostheses. Artegral imCrown, Merz Dental manufactures Pre-fabricated semi-individual polymer blanks (semi-finished) with a dentine enamel layer. The external contour corresponds to an anatomically complete anterior tooth crown, whereas the internal form of the crown is milled out of the internal volume of the blank.

C) Silica Based Ceramics

Silica based ceramic blocks are offered by considerable CAD/CAM systems. They are used for production of inlays, onlays, veneers, partial crowns and full crowns. Apart from monochromatic blocks, various manufacturers provide blanks with multi-coloured layers [IPS Empress CAD Multi (IvoclarVivadent)], for providing full anatomical crowns. Lithium disilicate ceramic blocks are particularly important in this group, due to their higher stability values; and they can be used for full anatomical anterior and posterior crowns, for copings in the anterior and posterior region and for three-unit FPD frameworks.[10,11]

D) Infiltration Ceramics

Blocks of infiltration ceramics reprocessed in porous, chalky condition and then infiltrated with lanthanum glass. These are available in three variations: Vita In-Ceram Alumina (Al_2O_3), Vita In-Ceram Zirconia and VITA In-Ceram Spinell.[12,13]

E) Zirconia Oxide

The application of CAD-CAM processing enabled the use of poly-crystalline zirconia coping and framework materials. Thepartially stabilized zirconiahas high stiffness and superior mechanical reliability. Zirconia oxide, sometimes called zircon, has unique physical characteristics that make it twice as strong and twice as durable as alumina-based ceramics.[14]

E) Glass Infiltrated CAD/CAM Ingots

Glass infiltrated CAD/CAM ingots have similar composition to slip cast ceramics, but starting with a porous ingot eliminates the complicated steps of slip casting. After milling porosity is eliminated by molten glass infiltration. Example of glass infiltrated ingots: In-Ceram Alumina (Vita Zahnfabrik), In-Ceram Spinell (Vita Zahnfabrik), In-ceram Zirconia. [14,15]

F) Materials for chairside CAD/CAM restorations:

- The CEREC acquisition center (AC) (Sirona)
- The E4D Dentist System (D4D Technologies)

COMMON CAD/CAM SYSTEMS

1. CEREC:

Cerec is an acronym for chair side economic reconstruction of esthetic ceramic. Cerec was introduced in 1980's, improvised cerec2 was introduced in 1996 and the advanced 3-D Cerec in 2000. Cerec 1 and Cerec 2, an optical scanner is used to scan the prepared tooth or impression which generates a 3-D image on monitor. A milling unit is used to fabricate the restoration. In Cerec 3-D, multiple images can be recorded within seconds, so clinicians can prepare multiple teeth in same quadrant and create a virtual cast for the entire quadrant.

CEREC IN-LAB SYSTEM

The CEREC inLab system is an evolution from the CEREC III system which used to produce one-visit inlays and onlays. The system is a independent scanning and milling unit deviced to fabricate single copings and three-unit FPD frameworks using interpenetrating phase compounds.[16]

Fig 6: The CEREC inLab system.

2) PROCERA

The PROCERA wasintroduced in 1987, designed by Anderson and developed by Bobelpharma. The Procera system (Nobelpharma Inc. Goteborg, Sweden) incorporates pantographic reproduction with electrical discharge (spark-erosion) machining. It produces titanium copings, which are subsequently veneered with compatible porcelain (Ti-Ceram) or composite to form crowns or bridges.[16]

Fig:7 The Procera system

3) LAVA

LAVA was introduced in the year 2002, Lava utilize a laser optical system to digitize information from multiple abutment margins and the edentulous ridge. The Lava CAD software automatically finds the margin and suggests a pontic. The CAM framework is designed to be larger to compensate for sintering shrinkage.[17]

4) EVEREST

Marketed in 2002, the Everest system consists of scan, engine, and the components. A digital 3D model is developed by computing 15 point photographs. The restoration is then framed on the virtual 3D model with Windows-based software. The milling unit has 5-axis movement that implement fabrication of detailed morphology and definite margins from a variation of materials including titanium, leucite-reinforced glass ceramics.[17]

5) CERCON

The Cercon System is generally referred as a CAM system because it does not have a CAD component. In this system scans the wax pattern and mills a zirconia bridge coping from pre-sintered zirconia blanks. Furthermore, in the Cercon heat furnace the copings are sintered. An in vitro study, showed the marginal adaptation for Cercon all-ceramic crowns and fixed partial dentures and reported the discrepancy as 31.3 µm and 29.3 µm.

A study carried out by McLean and Von Fraunhofer proposed that an acceptable marginal discrepancy for full coverage restorations should be less than 120 μm. The present research data indicate that most dental CAD/CAM systems are now able to produce restorations with acceptable marginal adaptation of less than 100 μm.[17]

Conclusion

CAD/CAM systems have upgraded dentistry by providing high-quality restorations. The evolution of current systems and the introduction of new systems demonstrate increasing user friendliness, expanded capabilities, and improved quality and range in complexity and application. Newer materials are more esthetic, wear more nearly like enamel and are strong enough for full crowns and bridges.

All these systems offer an alternative to the commonly practiced impressions-die-lost wax-casting technique. Viably, it can save the dentist's time by providing restorations that precisely fit the patient without requiring chair side modifications. Furthermore, they can render more persistence in restorative design and widen the possibility of a multitude of restorative materials, combining machinable tooth-colored ceramics.

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Conflicts of Interest

There are no conflicts of interest.

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