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Research Article
CAD-CAM: Emerging era in Dentistry

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Abstract

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. This article describes different CAD-CAM systems, configurations, capabilities and learning curves to use the systems successfully.

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. One visit treatment for indirect restorations has been made possible by technological development which enables distilization and replication of the complex topography of the tooth surface using computer-aided design / computer-aided manufacture (CAD/CAM).

Several techniques of varying degrees of sophistication have been introduced. The concept common to all the systems is that spatial information relating to soft or hard tissues may be processed as numerical data and manipulated by computer. Additionally the machining or manufacturing system is not material specific.

The first report on CAD/CAM, published in 1973, made it clear that the optical impression technique, or dental CAD/CAM, encompasses, all methods of analysis including diagnosis and treatment, working in space, ad developing means of measurement that preferably optical.

CAD/CAM means manufacturing the prosthesis directly with the data taken from the patient's mouth and at the utmost, it means staying analogical. In short, it is proceeding directly from paste to crown. The most topical example of a CAD/CAM system in the non-dental world is copying a drawing or sculpture with a pantograph.

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 the inlay.

During the next 5 years, little was done. The first dental CAD/CAM prototype was presented at the **Ganaciene Conference (France)** in 1983 and the first crown was publicly milled and installed in a mouth without any laboratory involvement in 1985.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.

General principles of CAD/CAM

All true CAD/CAM systems exhibit there computer-linked functional components, although the degree of sophistication may differ.

a. A means of data acquisition.
b. Restoration design.
c. Restorative production.

The first stage requires digital data to be collected from the patient's mouth, this is equivalent to traditional impression taking. The information may be stored in the form of three-dimensional coordinates of coils, on the surface of the oral tissues obtained with the aid of an intraoral camera on physical sensor. Resolution depends on the design of the individual system but it follow, that a laser beam offers greater accuracy than a contacting probe, whether in relation to soft tissue, tooth surface or cavity preparation.

Restoration design even when aided by computer, still relies to a large extent on the operators clinical knowledge but may be aided by the availability of digital information from the unprepared dentition and a library of performs. Future development of artificial intelligence systems may offer further assistance. Third is the Restorative production (CAM) system which includes a numerically controlled machine tool with four access capability. In this step of process, the lost wax technique is replaced by milling of a preformed cubical block of the material. This machine will automatically mill the prosthesis from conventional or special materials.

Uses:

- All CAD-CAM systems permit the production of restoration at the chairside.
- Eliminate potential inaccuracies associated with the traditional, multistage production of indirect restoration.
- Their use also minimizes cross infection.

Advantages:

- One visit procedure.
- No mercury involved.
- Looks great- available in multiple shades to better match natural tooth color.
- Saves time.
- Great longevity.

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.

Commercially Available Systems

1)The **CEREC** system[2,3,4,5], manufactured by Siemens Dental Corp. (Benshein, Germany) is a compact chairside system that consists of an optical data acquisition camera, CAD-CAM software and a micromilling machine.

2) **SOPHA:** This sophisticated French system, invented by Duret, allows for the production of inlays, anterior and posterior crowns and bridges. It also permits consideration of both static and dynamic occlusal factors. An impression of the tooth is taken using a lager imaging system and holography. Information from the light source is then digitized by the camera, presented on a video display and transferred to a CAD/CAM program that creates a model of the preparation.

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 [3]. 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.[3,4] The system is similar to a key copying or pantograph machine.

5)The **Procera** [3] 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 [3, 4] (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** [6] (Computer Integrated crown reconstruction) system is a registered trademark of Cicero Dental System B.V. (Hoorn, The Netherlands). The Cicero method for production of ceramic restorations uses official scanning, ceramic sintering, and computer assisted milling techniques to fabricate restorations with maximal static and dynamic occlusal contact relations.

8) The **COMET** [7] 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.

9) The **Japanese** system: Under the supervision of Professor Tsutsumy, this system has the three usual CAD/CAM components, i.e. the camera, the CAD and the NCMT. The system is only at the development stage, but its inventor, Dr. Fujita, has already produced some crowns with it. No clinical experience has been reported to date.

10) The **Dens** system: Developed by Rohleder and Kammer in Berlin, this system is still in its early stages of development. However, a prototype was introduced in Cologne this year. It comprises an optical sensor that is very fast and a NCMT that can work titanium and was developed to this end. It has no CAD yet. No clinical experience has been reported to date.

11) The **Krupp** system: This system deserves to be mentioned because it fails between the traditional method and the robot. Made with a special wax, the prosthesis is used to mould special electrodes that will reproduce the external and internal surfaces, separated at the line of the most important contours. The two moulded electrodes are used, as with the Procera system, to process by electro-erosion non-and semi precious metals of the Dentitan or Endocast type. It is possible to produce all-metal pieces like crowns and bridges using this system. No clinical experience has been reported to date, but the precision recognized by all who tried it is in the order of 40µm.

Comparison between different systems

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) [6] can mill single tooth restorations in the form of inlays, onlays, crowns and veneers. The DUX system produces copings while Procera [7, 8] 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 [4, 5] system was developed for the production of inlays, onlays, crowns and fixed partial dentures.

Materials available[9,10,11]

Wide ranges of materials are available for fabricating CAD-CAM restorations. 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).

Conclusion

The introduction of CAD/CAM in dentistry will influence the direction of clinical practice and research at universities. Results achieved must be analyzed with caution, but the extraordinary speed of development of this technology in industry affirms that it will be rapidly and definitively accepted in the dental profession. Its future evolution could be spectacular considering its numerous possibilities. All these systems offer an alternative to the currently practiced impressions-die-lost wax-casting technique. Potentially each can save the dentist's time by providing restorations that accurately fit the patient without requiring chairside adjustments. In addition, they can provide more consistency in restorative design and open the possibility of a array of different restorative materials, including machinable tooth-colored ceramics.

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