ORIGINAL RESEARCH PAPER

Dental Science

CAD/CAM DENTAL CERAMICS IN RESTORATIVE DENTISTRY

KEYWORD: Restorations, Prostheses, Orthodontic, Ceramics, Computer Aided Design, Computer Aided Manufacturing.

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ABSTRACT

Computer Aided Design and Computer Aided Manufacturing (CAD/ CAM) is a pair of often interdependent industrial computer applications that have greatly influenced the chain of processes between the initial design and the final realization of a product.

It refers to the computer software that is used to both design and manufacture products. It is 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. These are systems that can design and produce restoration out of blocks or blanks of ceramics. CAD/CAM is one of the highly competent dental lab technologies. Without this technology we wouldn't have the range and quality of products available. Hand-building and manual techniques still very much have their place and design education needs to treasure and foster these skills so that future generations will have the 'hands-on' skills to understand the man-made world and provide the next generation of engineers, designers and technicians.

CAD/CAM was first introduced to dentistry in the mid-1980s. Both chair side and chair side-laboratory integrated procedures are available for this restoration fabrication. In selecting which procedure to follow, consideration should be given to aesthetic demands, chair side time, laboratory costs, number of visits and convenience and return on investment associated with CAD/CAM equipment. Depending on the method selected, CAD/CAM ceramic blocks available for restoration fabrication include leucite-reinforced ceramics, lithium di silicate, zirconia, and composite resin. In order to determine which type of ceramic to use, the practitioner must take into account aesthetics, strength, and ease of customizing milled restorations. It gives both the dentist and the laboratory technician an opportunity to automate fixed restoration fabrication and to offer patients highly aesthetic restorations in just one or two visits. These technologies are responsible for massive gains in both productivity and quality, particularly since the 1980s. This article is to provide information on restorative procedures and ceramic materials using CAD/CAM technology.

INTRODUCTION

CAD/CAM technologies for superior product modelling in the intelligence of designing complete product variants become more and more pertinent in future. CAM software uses the models and assemblies created in CAD software to generate tool paths that drive the machines that turn the designs into physical parts. CAD/CAM software is most often used for machining of prototypes and finished parts. The technological changes taking place are truly revolutionizing the way dentistry is practiced and the manner in which laboratories are fabricating restorations. The advent of CAD/CAM has enabled the dentists and laboratories to harness the power of computers to design and fabricate aesthetic and durable restorations. The computer program displays a 3-D custom image of teeth and gums, allowing dentists to precisely design the tooth restoration with functional and aesthetic characteristics in mind. Once the restoration has been designed by the computer and cosmetic dentist, the information is sent to a sculpting machine (milling) which creates the restoration to the exact specifications of the design through CAM. There is no need for impression taking, temporaries or unnecessary reduction of healthy tooth structure. The technology is so precise that dental restorations made by CAD/CAM often fit better than those made by hand in a dental lab. One of the most effective uses of CAD/CAM in dentistry is the same-day porcelain crown, which removes several steps, including using a temporary plastic crown while a permanent crown is made by a laboratory. With CAD/CAM your restorations are placed in a single appointment. Because the most common CAD/CAM dental technologies use sculpted porcelain to create crowns and other types of dental fixtures such as inlays and onlays, the technology is even promoting safer dental restorations by reducing the use of metal amalgam fillings, which often contain traces of mercury. Dentists, who will be confronted with these techniques in the future, require certain basic knowledge if they are to benefit from these new procedures. This article gives an overview of CAD/CAM-technologies and ceramics available for dentistry today.

COMPONENTS OF CAD/CAM

All CAD/CAM systems consist of three components.

- A digitalisation tool/scanner that transforms geometry into digital data that can be processed by the computer.
- Software that processes data and, depending on the application, produces a data set for the product to be fabricated.
- A production technology that transforms the data set into the desired product.

SCANNER

Under the term 'scanner' one understands, in the area of dentistry, data collection tools that measure three-dimensional jaw and tooth

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 the one hand, on the other hand, some systems also offer the opportunity to design full anatomical crowns, partial crowns, inlays, inlay retained FPDs, as well as adhesive FPDs and telescopic primary crowns (Reiss, 2007). 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 (Mehl *et al,* 1997).

PROCESSING DEVICES

The construction data produced with the CAD software are converted into milling strips for the CAM-processing and finally loaded into the milling device. Processing devices are distinguished by means of the number of milling axes:

- 3-axis devices
- 4-axis devices
- 5-axis devices.

CAD/CAM PRODUCTION CONCEPTS IN DENTISTRY

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

- Chair side Production
- Laboratory Production
- Centralised fabrication in a production centre.

CHAIR SIDE PRODUCTION

All components of the CAD/CAM system are located in the dental surgery. Fabrication of dental restorations can thus take place at chair side 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. At present, only the CEREC System (Sirona) offers this possibility. Other producers also plan to introduce chair side CAD/CAM systems to the market. Since the CEREC system functions with water-cooling, a variety of materials can be processed, from glass-ceramic to high performance oxide ceramic. The first CAD/ CAM devices introduced were CEREC (Sirona) and Procera (Nobel Biocare). CEREC was originally introduced strictly as a chair side technique; the objective was to perform a one-visit procedure for fixed restorations, with a focus on the provision of inlays and onlays. In contrast, procera was introduced as a non chair side CAD/CAM device.

LABORATORY PRODUCTION

This variant of production is the equivalent to the traditional working sequence between the dentist and the laboratory. 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. 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.

Centralised Production

The third option of computer-assisted production of dental prostheses is centralised 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. As a result, the configuration of the prosthesis remains in the hands of the dental technician. The benefit of outsourcing CAM production is to be found in the small investment requirement, since only the digitalisation tool and software have to be purchased, still having access to a high quality production process. In addition, this procedure results in greater independence, since there is no relation to a particular production technology. It must, however, be noted that presently almost all CAD/CAM systems are only available as closed systems. In other words, if one acquires a scanner from one manufacturer, this implies, in the case of a closed system, that there is only access to that manufacturer's processes and line of products. In addition, the dental laboratory loses the income from producing the framework, since it is fabricated in the production centre. Many production centres also offer laboratories without a scanner the possibility of sending the master cast to the centre for scanning, designing and fabrication. The additional veneering of the frameworks for prosthetic restorations is carried out in the dental laboratory. Recently, dentists have been offered the possibility of sending the impression directly to the production centre (biodentis). This application is presently limited to ceramic inlays only.

An additional simplification in CAD/CAM production consists of intraoral data collection (optical impression). This means a digitalisation of what is now only an 'analogue' step in the production process. This could lead to additional improvement in quality and cost reduction. New software developments will make it possible to directly judge the quality of the preparation intra orally, before data are finally sent to the dental laboratory or production centre.

TYPES OF CAD/CAM RESTORATIONS

- Inlays and onlays
- Veneers
- Copings
- Substructures
- Full coverage crowns

CAD/CAM PROCESSING OF CERAMICS

Many systems are currently available using a variety of techniques and materials. Some examples of commercially available CAD/CAM systems are Cerec(Sirona), SironaInLab, Everest (kavo), Cercon(Dentsply), Lava(3M ESPE), Zeno (Welland), 5-tec(Zirkonzahn) etc. A typical procedural sequence for producing ceramic prostheses by CAD/CAM system is as follows:

- Set the blank in the milling machine holder according to the manufacturers instructions.
- Set the enlargement factor to compensate for sintering shrinkage. The factor will vary according to the overall size of the prostheses.
- Insert the appropriate machining\ milling tool.
- After machining is completed, remove the framework and residual blank.
- Cut the framework from the blank using a diamond disk.
- Clean the partially sintered framework completely.
- Dry the framework completely.
- Place the framework in the isothermal hot zone of the sintering furnace.
- Set the thermal processing conditions according to the sintering instructions for the specific product.
- Sinter the framework to achieve optimum density.
- After cooling, remove the sintered framework.
- Inspect the framework for surface and surface flaws using fiber-optic trans illumination.
- Evaluate the framework for adequacy of wall thickness, ease of setting, marginal fit.
- If necessary, use a water cooled diamond tool to preform mirror adjustment corrections.
- Rinse the framework thoroughly with water and dry it completely.
- Depending on the zirconia product, the framework maybe used with or without a veneering ceramic. If a veneering ceramic is indicated, a transitional liner maybe required prior to the application of the veneering (layering) ceramic.

CAD/CAM RESTORATIVE TECHNIQUE

Using a CAD/CAM restorative technique, a number of steps can be simplified or eliminated. Traditional impressions can be replaced by use of a handheld scanning device that digitally records the form and margins of the preparation. Care must be taken to ensure that the whole preparation is scanned, to avoid introducing errors. As with a traditional impression, soft tissue retraction and hemostasis are prerequisites for an accurate result. In fact, these steps are more critical for CAD/CAM preparation scanning than with traditional impressions. While impression material has some tolerance for small amounts of sulcular fluid, and light-body material can flow into deeper subgingival margins, scanners require a dry field and soft tissue that must be thoroughly separate at the level of the margin from the hard tissue. For this reason, it has been suggested that a soft tissue diode laser (Odyssey Navigator, Ivoclar Vivadent; GENTLEray 980, Kavo; DioDent Micro 980, HOYA ConBio) be used to expose subgingival margins. The soft tissue diode laser has been found to offer precision, to result in a narrow band of lased tissue, and to produce good hemostasis (Stübinger *et al*, 2006). Good healing has also been the case following use of diode lasers on gingival tissues (Romanos *et al,* 1999). Selecting a laser with sterilizable sleeves assists with infection control, and portability and precut laser tips aid convenience (Odyssey Navigator). Alternative soft tissue management techniques include electrosurgery and one of the standard manual retraction techniques. In addition, a modified preparation design may be necessary.

Depending on the system used, the clinician can see the preparation magnified on the computer screen as the scan is being processed. This visualization - also available with intraoral cameras and operating microscopes -enables early detection of any preparation design defect, which can then be adjusted before the preparation is rescanned. In addition, the interocclusal distance and space created by preparing the tooth can be assessed by the software, enabling the dentist to make adjustments, if necessary. Two basic techniques can be utilized for CAD/CAM restorations. One is strictly chairside - a single-visit technique – while the other involves an integrated chairside-laboratory CAD/CAM procedure.

CERAMIC MATERIALS FOR CAD/CAM PROCESSING

Many ceramic materials are available for use as CAD/CAM restorations. Common ceramic materials used in earlier dental CAD/CAM restorations have been machinable glass ceramics such as Dicor-K or Vita Mark II. Although monochromatic, these ceramic materials offer excellent esthetics, biocompatibility, great color stability, low thermal conductivity, and excellent wear resistance. They have been successfully used as inlays, onlays, venners and crowns.

SILICA BASED CERAMICS

Grindable silica based ceramic blocks area offered by several CAD/CAM systems for the production of inlays, onlays, veneers, partial crowns and full crowns (fully anatomical, anatomically partially reduced). In addition to monochromatic blocks, various manufacturers now offer blanks with multi-coloured layers [Vitablocs TriLuxe (Vita), IPS Empress CAD Multi (IvoclarVivadent)], for the purpose of full anatomical crowns. Due to their higher stability values, lithium disilicate ceramic blocks are particularly important in this group; 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 in the anterior region due to their high mechanical stability of 360 MPa (Taskonak *et al*, 2006). Glass ceramics are particularly well suited to chairside application as a result of their translucent characteristics, similar to that of natural tooth structure; they provide aesthetically pleasing results even without veneering. As a result of their relatively high portion of glass, these ceramics are, in contrast to oxide ceramics, etchable with hydrofluoric acid and thus can be inserted very well using adhesive systems(Sorensen *et al*, 1991).

INFILTRATION CERAMICS

Grindable blocks of infiltration ceramics are processed in porous, chalky condition and then infiltrated with lanthanum glass. All blanks for infiltration ceramics originate from the Vita In-Ceram system (Vita) and are offered in three variations:

- Vita In-Ceram Alumina (Al_2O_3): suitable for crown copings in the anterior and posterior region, three-unit FPD frameworks in the anterior region
- Vita In-Ceram Zirconia (70% Al_2O_3, 30% ZrO_2): suitable for crown copings in the anterior and posterior region, three-unit FPD frameworks in the anterior and posterior region. Thanks to its superior masking ability this ceramic is suitable for discoloured abutment teeth(Raigrodski *et al* , 2002)
- VITA In-Ceram Spinell ($MgAl_2O_4$): has the highest translucency of all oxide ceramics and is thus recommended for the production of highly aesthetic anterior crown copings, in particular on vital abutment teeth and in the case of young patients.

Oxide High Performance Ceramics

At present, aluminum oxide and zirconium oxide are offered as blocks for CAD/CAM technology.

Aluminum Oxide (al_2o_3)

This oxide high performance ceramic is ground in a pre-sintered phase and is then sintered at a temperature of 1520°C in the sintering furnace. Aluminium oxide is indicated in the case of crown copings in the anterior and posterior area, primary crowns and three-unit anterior FPD frameworks. The ground frames can be individually stained in several colours with Vita In-Ceram AL Coloring Liquid. (Dunnet *et al* , 2007) Examples of grindable aluminum oxide blocks: In-Ceram AL Block (Vita), inCoris Al (Sirona) available in an ivory-like colour (Color F 0.7).

Yttrium Stabilised Zirconium Oxide (zro_2, Y-tzp

Zirconium dioxide is a high-performance oxide ceramic with excellent mechanical characteristics. Its high flexural strength and fracture toughness compared with other dental ceramics offer the possibility of using this material as framework material for crowns and FPDs, and, in appropriate indications, for individual implant abutments. The addition of three molecules of Y_2O_3 results in a stabilising tetragonal phase at room temperature, which, as a result of a transition to a monoclinic phase can prevent the progression of cracks in the ceramic (Transformation strengthening). (Sailor *et al* , 2007)Examples of Zirconium oxide blocks: Lava Frame (3M ESPE), Cercon Smart Ceramics (DeguDent), Everest ZS und ZH (KaVo), inCoris Zr (Sirona), In-Ceram YZ (Vita), zerion (etkon) and Zeno Zr (Wieland-Imes)

Classification of Machinable Ceramic Blanks

- Feldspathic porcelain blanks (Vita)
- Glass ceramic blanks
- Tetrasilici fluromica based glass ceramic
- Leucite based
- Lithia disilicate glass ceramic
- Glass infiltrated blanks
- Alumina (Vita In-Ceram Alumina)
- Spinell (Vita In-Ceram Spinell)
- Zirconia (Vita In-Ceram Zirconia)
- Presintered blanks
- Alumina (Vita In-Ceram AL)
- Ytrria stabilized Zirconia (Vita In-Ceram YZ)
- Sintered blanks
- Ytrria stabilized Zirconia (Everest ZH blanks)

ADVANTAGES OF CAD/CAM TECHNOLOGY

The many benefits associated with CAD/CAM generated dental restorations include: the access to new, almost defect-free, industrially prefabricated and controlled materials; an increase in quality and reproducibility and also data storage commensurate with a standardised chain of production; an improvement in precision and planning, as well as an increase in efficiency. The advantages of the method also includes its simplicity the laboratory is not required, there is no classical impression procedure, rapid fabrication, acceptable cost, and the fabricated restoration id of the same or higher quality than the laboratory fabricated restoration. Also the accuracy of shape prevents gapping between tooth crowns and surrounding teeth. Immediate 3D images remove the need for taking time-consuming impressions of teeth. Computer sculpting creates a much healthier restoration for the tooth in a matter of minutes. Short sculpting time allows the dentist to place your dental restoration during the same visit, instead of requiring two visits . CAD/CAM restorations are better-fitting, more durable and more natural looking (multi-colored and translucent, similar to natural teeth) than previously machined restorations.

SIGNIFICANCE FOR THE DENTIST

In recent years, the use of CAD/CAM technology has above all strongly influenced dental-technical production procedures. If one ignores chair side prostheses, the significance of this technology for the dentist is not immediately clear. In recent years, CAD/CAM production has clearly expanded the palette of materials for dental prostheses by providing access to new ceramic materials with high dependability (Tinschert *et al*, 2001). The stability values of zirconium oxide ceramics permit, in many areas of indication, the use of this material as an alternative to metal frames for permanent prostheses.The production of long-term temporary prostheses has, as a result of the use of a virtual wax up on the computer, become faster, more convenient and more predictable. This method has already been implemented by computer-generated long-term temporary restorations, since it can be modified, by changing the form, to the functional and aesthetic satisfaction of the patient during a clinical test phase. The production of the definitive prosthesis should also be carried out by CAD/CAM technology and represents merely a copying process of the temporary prosthesis into the definitive prosthesis by a different material.

In spite of all the benefits of these new methods, the dentists working procedures will have to be adapted to the methods of CAD/CAM and milling technology. These include appropriate tooth preparations with the creation of a continuous preparation margin, which is clearly recognisable to the scanner, for example in the form of a chamfer preparation. Shoulder less preparations and parallel walls should be avoided. On the basis of present knowledge, a tapered angle of between 4° to 10° is recommended (Vult et al, 2005). Subsections and irregularities on the surface of the prepared tooth as well as the 'creation of troughs' with a reverse bevel preparation margin can be inadequately recognised by many scanners .In addition, sharp incisor and occlusal edges are to be rounded. Sharp and thinly extending edges as well as 90° shoulders in a ceramic restoration can result in a concentration of tension; in addition sharp edges cannot be milled exactly using rounded grinders in the milling device.The diameter of the smallest grinder is 1 mm in most systems, so structures smaller than 1 mm cannot be milled precisely.The result is an inaccurate fit.

CONCLUSION

CAD/CAM systems offer automation of fabrication procedures with standardisation quality in a shorter period of time. They have the potential to minimize inaccuracies in technique and reduce hazards of infectious cross contamination. It allows application of newer high strength with outstanding biocompatibility combined with adequate mechanical strength, provisions for aesthetic designs, excellent precision of fit and longetivity. However, these advantages must be balanced against the high initial cost of CAD/ CAM systems and the need for additional training. Patients expectations, financial constrain, operator's preference' as well as availability of CAD/CAM systems will dictate the suitability basis in the future. CAD/CAM is increasingly used, and it can be anticipated that its use will continue to increase, especially with the availability of direct image transfer scanners from the chair to the dental laboratory and between laboratories. Innovations will continue to affect and challenge dentistry.

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