CAD-CAM the future of digital dentistry: a review

Reeta Jain[1,*], Raghav Takkar[2], G.C Jain[3], R.K Takkar[4], Nitin Deora[5]

[1]Professor & Head, [2]PG Student, [4]Private Practitioner, [5]Reader, Dept. of Prosthodontics & Crown Bridge, [3]Reader Dept. of Oral Maxillofacial Surgery, Genesis Institute of Dental Sciences & Research, Ferozepur

***Corresponding Author:**
Reeta Jain
Professor & Head, Dept. of Prosthodontics & Crown Bridge, Genesis Institute of Dental Sciences & Research, Ferozepur
Email: rtjn132@gmail.com

Abstract

CAD/CAM called as Computer Aided Design/Computer Aided Manufacturing was introduced to dentistry in the mid-1980s. CAD/CAM restoration fabrication is available as both chairside and chair side—laboratory integrated. In the past 20 years, there have been new developments in dental materials and computer technology which has led to the success of CAD/CAM technology. The development of information technology has helped us to devise and build 3D models, based on virtual prototypes with the help of a computer numerical control (CNC) device. Computers can now be used to create accurately detailed projects that can be assessed from different perspectives in a process known as computer aided design (CAD). To materialize virtual objects using CAD, a computer- aided manufacturing (CAM) process has been developed. CAM operates using a machine connected to a computer to convert a virtual file into a real object. CAD/CAM technology employs a non-invasive three dimensional (3D) imaging system. This paper gives you a brief knowledge about the types and uses of CAD/CAM technology.

Key words: CAD/CAM, Digitizing, 3D Printing, Stereolithography

Introduction

Recent growth trends of CAD/CAM systems for industrial applications in rapid prototyping have facilitated significant improvement in software and a reduction of size and costs of machinery. Such trends have allowed for CAD/CAM to be adopted into numerous other fields, including medical and dental applications. CAD/CAM in dentistry has been particularly useful in permitting the fabrication of custom, patient-specific restorations and prosthetics without having to use traditional analoge dental laboratory methods.

Computer-aided systems depend on a 3-D data set representing either the prepared tooth or a wax model of the desired substructure. This 3-D data set is used to directly machine fully-dense ceramics (e.g., MK II, Vita, Bad Sa¨ckingen, Germany; Empress CAD, Ivoclar Vivadent Schaan, Liechtenstein), to create an enlarged die upon which ceramic powder is packed e.g., (Procera, Nobel Biocare, Gothenburg, Sweden) or to machine an oversized part for firing by machining blocks of partially fired ceramic powder; a process termed 'green machining' (e.g., Cercon, Dentsply Prosthetics, York, PA, USA.; Lava, 3MESPE, St. Paul, MN, USA; YZ, Vita, Zahnfabrik).

Historical Background[1]

- 1971 - Duret introduced CAD/CAM technology in dentistry.
- 1983 - First dental CAD/CAM restoration was manufactured.
- Duret begun the fabrication of crowns with the help of an optical impression of the preparation in the mouth in which designing was done using functional movements, and then the milling was done in a milling machine that was numerically coordinated.
- The Sopha system developed by Duret became a landmark in the development of the current dental CAD/CAM.
- 1979- Heitlinger and Rodder milled the equivalent of the stone model to make the crown, inlay or pontic.
- In 1980 Moermann et al. took a picture of the internal surface of the inlay and milled it.
- CEREC[1] - First to be introduced for dental purpose in the mid 1980's. Developed by Siemens Corporation.
- 1987 - CEREC system stands for "CHAIR SIDE ECONOMICAL RESTORATION OF ESTHETIC CERAMIC".
- 1994 - 2nd generation CEREC[2] system developed by Siemens Corporation.
- 1999 - 3rd generation CEREC[3] system developed by Sirona, Benheim, Germany.
- The CEREC[3] system (Sirona) had several technical improvements over CEREC[2], including the three-dimensional (3D) CEREC[3] intraoral camera, manipulation of the picture, and the grinding unit.
- Dr. Andersson in 1987 designed the Procera system which marked the beginning of a new era in dental CAD-CAM systems.
- He also fabricated titanium copings by spark erosion.
- This system was used for all-ceramic frameworks.

CAD/ CAM

Procedure: A CAD/CAM system consists of a process chain which includes scanning, designing and milling. The scanning device converts the shape of the prepared teeth into voxels (3-D units of information). The operator designs a restoration shape using the computer generating a tool path, used by the milling device to create the shape from a restorative material.[2]

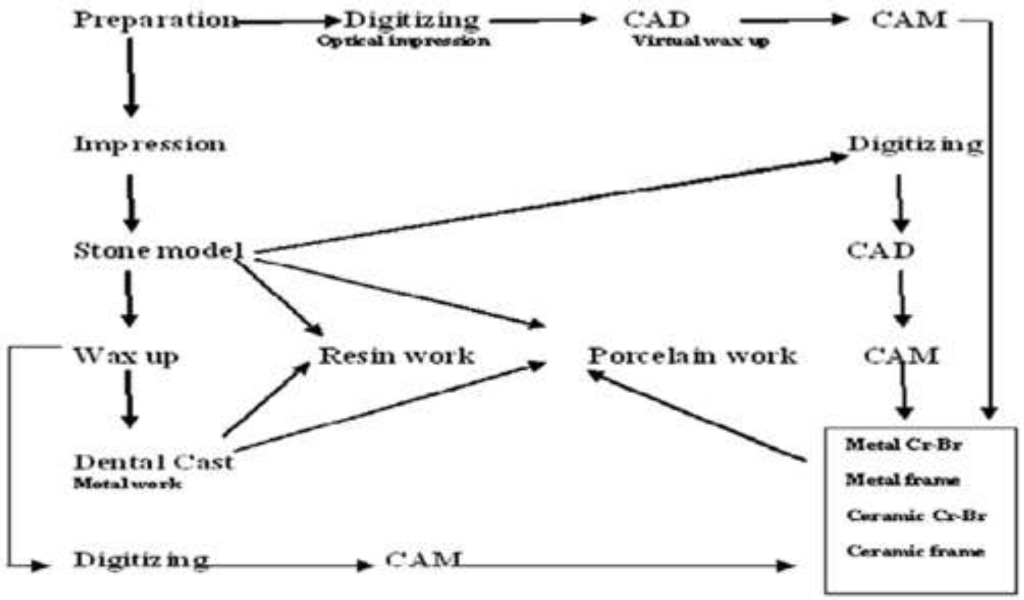

Fig. 1: Overview of CAD/CAM Process

Processing Techniques

There are two types of processing techniques:

- Additive manufacturing
- Subtractive manufacturing.

Additive Manufacturing[(3)]: Additive manufacturing process takes the information from a CAD file which is then converted to a stereolithography (STL) file. The drawing made in this process is approximated by triangles and slices which provide the information of each layer that is going to be printed.

- Rapid Prototyping/3D Printing
- The STL File
- Fused Deposition Modeling
- Selective Laser Sintering
- Rapid Prototyping/3D Printing[(3)]: The first form of creating layer by layer a three-dimensional object using computer aided design (CAD)

Became possible by other technologies, which are

- Computer-aided design (CAD),
- Computer-aided manufacturing (CAM), and
- Computer numerical control (CNC).

3D Printing technologies are used widely in the medical industry:

- Stereolithography[(2)]- Stereolithography (SL) which was developed by 3D Systems, Inc.,
  - It is a liquid-based process
  - It consists of curing or solidification of a photosensitive polymer after an ultraviolet laser makes contact with the material.
  - The model in a CAD software is translated to a STL file in which the pieces are "cut in slices" which further provide the details for each layer.

The STL File[(3)] –

- Standard Tessellation Language.
- In STL file there is conversion of the continuous geometry in the CAD file into small triangles, or coordinates triplet and the normal vector to the triangles.
- This process is not accurate because the smaller are the triangles the closer is the preparation to reality.

Fused Deposition Modeling[3]-

- Fused deposition modeling (FDM) is an additive manufacturing process in which a thin filament of plastic feeds a machine where a print head melts it and extrude it in a thickness typically of 0.25 mm.
- Materials used in this process are polycarbonate(PC), acrylonitrile butadiene styrene(ABS), polyphenylsulfone(PPSF), PC-ABS blends, and PC-ISO, which is a medical grade PC)
- The main advantages of this process
  - No chemical post-processing required,
  - No resins to cure,
  - Less expensive machine, and
  - Materials resulting in a more cost effective process.

The disadvantages are:

- The resolution on the axis is low compared to other additive manufacturing process (0.25 mm), so a finishing process is required for a smooth surface which is a slow process requiring days to build large complex parts.

Selective Laser Sintering[3]-

1. This is a three-dimensional printing process in which a powder is sintered or fuses by the application of a carbon dioxide laser beam.
2. The material is heated in the chamber to almost its melting point.
3. The powder is fused by laser at a specific location for each layer specified by the design.

This process can be used for a lot of materials:

- Metals, combination of metals, plastics, combinations of metals and polymers, and combinations of metals and ceramics.

The Advantage of this technology is the wide range of materials that can be used.

- Subtractive Technologies

1. Subtractive processes also called Machining, such as milling, turning or drilling, used carefully planned tool movements to cut away material from a work piece to form the desired object.
2. Consolidation processes such as casting or molding, use custom designed tooling to solidify material into the desired shape.

CAD/CAM Systems[4]:

Based on their production methods systems have been divided into the following:

1. **In office system:** Most widely used is Cerec System. Intraorally scanning of the preparation and selection of appropriate materials is done by this system due to which the restorations can be fabricated and seated within a single appointment.
2. **CAD/CAM- Dental laboratory systems:** The indirect systems scan a stone cast or die of the prepared tooth, in the dental lab (eg Cerec-in lab). Many of these systems produce copings after which the dental technician adds esthetic porcelain to the restoration.
3. **CAD/CAM using networks for outsourcing dental lab work:** Technologies using CAD/CAM with network machining center which means outsourcing the framework fabrication using an internet have been introduced as the design and fabrication of the framework for high strength ceramics is technique sensitive.

Most Common Cad/Cam Systems

Cerec[4]: Chair Side Economic Reconstruction of Esthetic Ceramic. Cerec was introduced in 1980s followed by an improved version cerec[2] which was introduced in 1996 and finally the advanced 3-D Cerec 3 in 2000. In Cerec[1] and Cerec[2], an optical scanner is used to scan the preparation or the impression and a 3-D image is formed on the monitor. There is a milling unit to prepare the restoration. With newer Cerec 3-D, the operator can record multiple images within a few seconds, which enables the clinician to prepare multiple teeth in same quadrant thereby creating a virtual cast for that quadrant.

Cerec in-lab is a system which scans dies with laser and the resultant image is displayed on the screen. The VITA In-cream blocks are used for milling after the designing.

DCS Precident[4]: Consists of a laser Scanner called as Preciscan and a multitool milling center called Precimill CAM. The DCS software automatically provides suggestions for connector sizes and pontic forms. It can scan upto 14 dies simultaneously and mill 30 frameworks in one fully automated operation. It can also mill titanium and fully dense sintered zirconia. An in vitro study showed that marginal discrepancies of alumina and zirconia based posterior fixed partial denture machined by the DCS system was between 60 μm to 70μm.

Cercon[4]: It is commonly called as a CAM system as it does not have a CAD component. This system scans the wax pattern and mills a zirconia bridge coping from presintered zirconia blanks, which is sintered at 1,350^{0}C for 6-8 hrs. Veneering is done later on to provide esthetic contour. Marginal adaptation for the cercon crowns and fixed partial dentures was reported 31.3 μm and 29.3 μm respectively.

Procera All Ceram System[7] was introduced in 1994. It is the first system which provides outsourced fabrication using a network connection. After the master die is scanned all the 3-D images are transferred to the processing center through an internet link where an enlarged die is milled by a computer controlled milling machines. The coping is sent to the lab for veneering of porcelain. According to research data average marginal gap for Procera all Ceram restoration ranges from 54 μm to 64 μm.

CICERO system (computer integrated crown Reconstruction) it was introduced by Denison et al in 1999, it includes optical scanning, metal and Ceramic sintering and computer assisted milling to obtain restoration.

The aim of CICERO is mass production of ceramic restorations at one integrated site. It includes rapid custom fabrication of high strength alumina coping and also partially finished crowns to be delivered to dental laboratories where porcelain layering or finishing can be done.

Lava CAD/CAM System was introduced in 2002, and is mainly used for fabricating zirconia framework for the all ceramic restorations. Yttria stabilized tetragonal zirconia poly crystals (Y-TZP) are used in this system are better than the conventional ceramics as they have greater fracture resistance. Lava system uses a laser optical system to transfer and digitize information received from the preparation. The Lava CAD software suggests a pontic automatically according to the margin.

Studies on marginal adaptation of Y-TZP bridges processed with Lava system for 2 milling times (75 mins Vs 56 mins) did not affect the marginal adaptation (61 ± 25 µm Vs 59 ± 21 µm).[9]

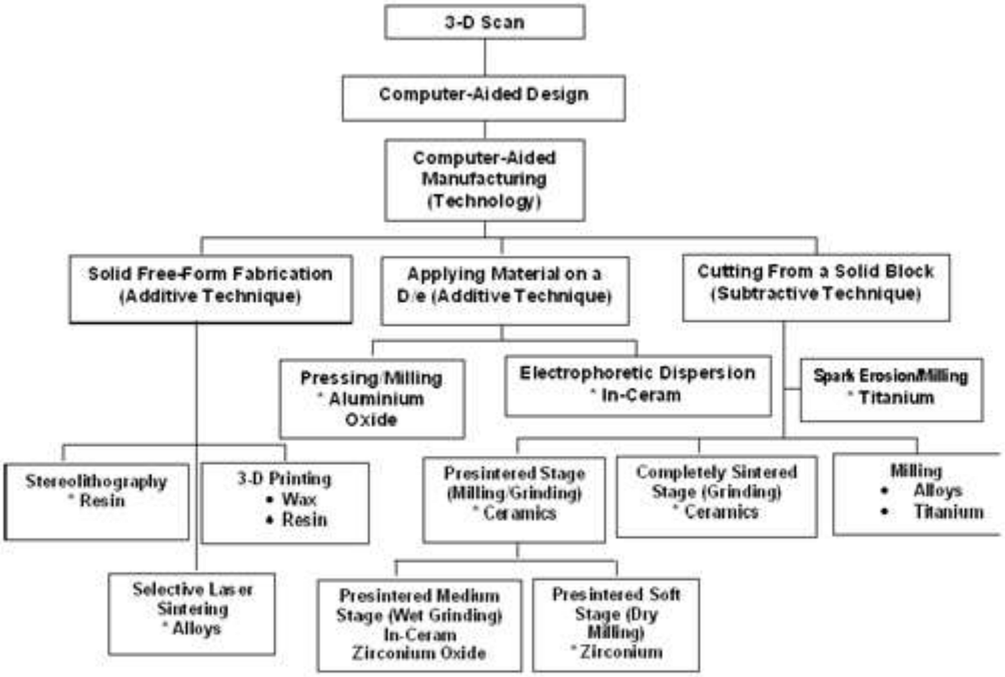

Fig. 2: Overview of CAD/CAM manufacturing systems for dentistry [10]

Conclusion

CAD/CAM systems offer automatic fabrication procedures which help to standardize the quality and decreased time span. They also have the potential to reduce inaccuracies in the technique and minimize the hazards of cross infections. It allows the dentist to use newer high strength materials with outstanding biocompatibility and adequate strength, excellent precision of fit. In future the expectations of the patients, the preference of the operators and the financial constrain, as well as availability these systems will dictate the suitability of this type of restorations.

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