Computer Aided Designing-Computer Aided Milling in Prosthodontics: A Promising Technology for Future

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Computer aided designing-computer aided milling (CAD-CAM) technology was introduced to dentistry way back in 1971. Over the years there has been a constant upgradation in the quality and popularity of its application to dentistry. CAD-CAM fabricated prosthesis though initially were considered costly and technique sensitive, nowadays they are being extensively used because of advancements in various CAD-CAM systems that have gained popularity. The ease of work and reduced chair side time makes them a boon while providing prosthodontics treatment. Dental CAD-CAM systems are being used not only for crowns and bridges, inlays and onlays but also for fabrication of removable prosthesis, stents, and implant components. This article reviews the evolution of the CAD-CAM system and its applications in the field of dentistry over the past two and a half decades.

Keywords: Computer aided designing-computer aided milling, Crowns, Inlays, Onlays, Rapid prototyping, Stereolithographic image, Standard tessellation language format, Surgical stents

INTRODUCTION

CAD refers to computer aided designing, CAM refers to computer aided milling or machining. This process is sometimes referred to as CAD-computer-integrated manufacturing (CIM) process, where CIM refers to computer integrated machining or milling. Ever since the introduction of CAD-CAM to dentistry, there has been a constant phase of advancement to the technology.¹ CAD/CAM technology fabricates prosthesis directly from the data obtained from the patient’s mouth. CAD CAM has been used not only for replacement of missing or cavitated dentition, but also for the fabrication of maxillofacial prosthesis, for implant prosthesis and also for numerous research studies.

HISTORICAL BACKGROUND

The CAD/CAM technology was introduced by Duret in 1971 in restorative dentistry and in 1983, the first dental CAD/CAM restoration was manufactured.¹² Initially CAD-CAM was used for large industrial projects that has made their production easier and faster. Unlike today, dental CAD-CAM was not very popular due to a number of factors that included: The cost of the equipments and the time needed, the precision needed while recording the details of the site of preparation of the restoration, precision in the final milling of the accurate restoration.³

From 1971 Duret started fabrication of crowns in which occlusal surface was made using an optical impression of the abutment tooth in the mouth, and designing was planned using functional movements, Duret then milled a crown with a milling machine that was coordinated numerically. The Sopha system developed by Duret became a landmark in the development of the current dental CAD/CAM.¹²

In 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 single picture of the tooth preparation and milled only the internal surface of the inlay.⁴

The CEREC 1 system was the first to be introduced for dental purpose that marked a landmark in the mid 1980’s. It was developed by Siemens Corporation. The ceramic reconstruction or CEREC system stands for “Chair side economical restoration of esthetic ceramic” and was first introduced in 1987.⁴ Siemens Corporation later developed the second generation CEREC 2 system in 1994 and Sirona, Benheim, Germany brought the third generation CEREC 3 system in 1999. It was originally developed by Brains AG, and the first fully operational CAD-CAM system marketed for use in clinical dentistry.³ The CEREC 3 system (Sirona) has several technical improvements over CEREC 2, including the three-dimensional (3D) CEREC 3 intraoral camera, manipulation of the picture, and the grinding unit.

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Leinfelder (1989) studied that the CAD-CAM CEREC system was a small, complex unit developed for electronically designing and milling ceramic restorations.

The next milestone in dental CAD-CAM systems was crossed by Dr. Andersson in 1987 who designed the Procera system. He attempted fabrication of titanium copings by spark erosion. He introduced CAD/CAM technology for processing composite veneered restorations. This system was used around the world for the fabrication of all-ceramic frameworks for a long time. The current Procera system developed by Nobel Pharma, Inc., Goteborg, Sweden uses a copying and fabrication system with a pantograph and spark erosion. He introduced CAD/CAM technology for processing composite veneered restorations. This system was used around the world for the fabrication of all-ceramic frameworks for a long time. The current Procera system developed by Nobel Pharma, Inc., Goteborg, Sweden uses a copying and fabrication system with a pantograph and electric discharge machining. The pantograph stylus reads the die and the shapes of wax pattern and these shapes are then fed into a milling machine to produce electrodes in these shapes. These electrodes are used for the production of the final restoration using the electric discharge machining.6

The Dux system, also known as the Titan system developed by DSC Dental, Allschwill, Switzerland, consisted of a precision contact digitizing sensor attached to a computer system and a milling machine. The Dux system claims to have an accuracy in the order of 30 (±20) μm and the milling process takes about 10 min.7

The Celay system developed by Mikrona Technologic, Spreitenbach, Switzerland in 1990 was a very small unit. It consisted of a contact digitizer that records the shape of an acrylic inlay and directly transfers the shape to a milling machine.7,8

The Denticad system developed by BEGO, Bermen, (Germany), and Denticad, Waltham, (USA), the Mass system consisted 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 was directly controlled by the computer.7,8,10

The computer integrated crown reconstruction (CICERO) system was developed by CICERO Dental System B.V. (Hoor, 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. The system makes use of optical scanning, near net-shaped metal, ceramic sintering and computer-aided fabrication techniques.11

The Coordinate Measuring Technique System developed by Steinbichler Optotechnik Technique GMBH, Neubeuern, Germany allows the generation of a 3D data record for each superstructure, with or without the use of a wax pattern. The system used a combination of strip projection methods with triangulation, enabling measurement of the coordinates of all measurement points recorded by a charge-coupled device camera not only with high precision but also at a high speed.7

Lava CAD/CAM System was introduced in 2002. It has been used for fabrication of zirconia frameworks in all ceramic restorations. The Lava system utilizes yttria stabilized tetragonal zirconia poly crystals which has a greater fracture resistance than the conventional ceramics. Lava system uses a laser optical system to digitize information.10,12,13

Current trends and applications of CAD-CAM systems

The Cercon Zirconia system developed by Dentsply Ceramco, Burlington, NJ, USA is used for the production of Zirconia - based prostheses. After preparing the abutment teeth an impression is made and sent to the laboratory, where it is poured into a model. A wax pattern is made for each coping or the crown areas of the framework of a fixed partial denture. The pattern is scanned and the blank is rough-milled and fine-milled on occlusal and gingival aspects in an enlarged size to compensate for the 20% shrinkage that will occur during subsequent sintering at 1350°C.14,15

Now-a-days CAD-CAM is also being used for the fabrication of complete dentures and removable partial denture frameworks.16 The removable partial denture frameworks is made using rapid prototyping, stereolithographic technique. It was developed by 3D Systems of Valencia, CA, USA in 1986. A CAD model is constructed by scanning the impressions of the patient and stored in standard tessellation language (STL), which is a stereolithographic image. The Rapid Prototyping machine processes the STL file by creating sliced layers of the model. The first layer of the physical model is created. The model is then lowered by the thickness of the next layer, and the process is repeated until completion of the model occurs. The model and any supports are removed after the completion of the process. The surface of the model is then finished and cleaned.16-18

Initially the use of CAD-CAM focussed on the fabrication of fixed restorations such as inlays, onlays, crowns and bridges. The inability to scan and read the soft tissue and the interocclusal relationship was a setback in fabrication of complete and partial dentures. In the recent years, advancements in the CAD-CAM technology has facilitated fabrication of complete and partial removable dentures. The fabrication of complete denture using CAD-CAM involves
impression making with rubber-base impression material in a specially designed double impression tray. These trays are adjusted at a certain vertical dimension in the patient’s mouth and are then retrieved and transferred to the 3D laser scanning system. The impressions are scanned and a 3D digital model is obtained. This data can be used for arrangement of teeth after selection of the shade. The 3D image is used for development of a 3D model of the denture to be fabricated and then it is milled using a milling unit.

INTEGRATED IMPLANTOLOGY

Nowadays there is a greater interest in the CAD-CAM systems for implant-supported prosthesis, as they have been used for the manufacture of implant abutments and surgical stents in implant dentistry. Ideally, the abutment head should resemble a prepared tooth with good form, morphology and emergence profile. Proper implant positioning and appropriate preparation of hard and soft tissue is critical to create optimal emergence profile, function, esthetics, and periodontal health. A custom design, perfect fit and higher resistance are the main characteristics of CAD-CAM implant abutments. CAD-CAM surgical templates allow transferring the software planning to the surgical field.

The various types of implant abutments can be classified into three categories:
1. Stock (prefabricated) abutments: They are milled in different materials (titanium, zirconium) using CAD-CAM technology. These are available either straight or preangled.
2. UCLA (laboratory wax and cast) abutments: They are manufactured from a gold platform and a castable sleeve that allows individualizing the shape and height.
3. Computer-milled solid abutment abutments: A solid block of titanium is milled using a computerized milling machine to the operator’s specifications.

In the more recent times, CAD-CAM has also been used for fabrication of maxillofacial prosthesis using rapid prototyping procedure. Use of CAD-CAM for fabrication of maxillofacial prosthesis has helped in more accurate shade matching and providing precise anatomic features. The process involves scanning of the site and the donor ear using a scanner and transmitting the STL format into a prototyping machine.

CAD-CAM components and procedure

The CAD-CAM system is composed of a scanning unit that is composed of a high resolution camera that reads the finest details of the surface to be scanned. The scanned data is converted into STL format. The STL format is the format that is readable by most of the CAD-CAM software.

This STL format is transferred to the milling system that is attached to the computer. The STL data is used for milling the required prosthesis that has been designed using a CAD-CAM software (Table 1).

The conventional technique for fabrication of prosthesis involves preparation of abutments, impression making followed by model production, wax up, and then casting, but the CAD-CAM technology involves direct digitization of abutment teeth inside the oral cavity instead of taking conventional impressions. The restorations are designed on a computer using CAD software based on the digitized data that acts as a virtual wax-up. The restorations are processed using a computer assisted milling machine. In the more recent times to counteract the difficulty of accurately scanning the abutments and the adjacent teeth, stone models are poured after impressions and these stone models are scanned using the scanning system and the STL image thus obtained is used for milling the prosthesis. The entire process of electronic designing and subsequent milling of a ceramic restoration requires approximately 25 to 30 min.

ADVANTAGES OF CAD-CAM SYSTEMS

CAD-CAM technology has brought about a revolution in the modern dental practice. Use of CAD-CAM serves the following advantages.

Application of new materials

Advancement and development in the material science has constantly motivated to develop newer manipulation techniques also. Introduction of high-strength ceramics brought into consideration of processing FPD frameworks but it was difficult to process them using conventional dental laboratory technologies. Such high strength dental ceramics could be better used with the CAD/CAM technology for processing fixed prosthesis.

Table 1: The various CAD-CAM systems, the type of production unit and the method of scanning used by the system

<table>
<thead>
<tr>
<th>CAD-CAM system</th>
<th>Type of Production</th>
<th>Method of Scanning</th>
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<tbody>
<tr>
<td>CEREC 1/2/3</td>
<td>Direct in-office</td>
<td>Laser</td>
</tr>
<tr>
<td>Denticad</td>
<td>Direct in-office</td>
<td>Contact probe</td>
</tr>
<tr>
<td>Sopha</td>
<td>Direct in-office</td>
<td>Holography and laser</td>
</tr>
<tr>
<td>Celay</td>
<td>Indirect in-office</td>
<td>Contact probe</td>
</tr>
<tr>
<td>Procera</td>
<td>Industrial outsourcing using networks</td>
<td>Contact probe</td>
</tr>
<tr>
<td>CEREC in-Lab</td>
<td>Dental laboratory</td>
<td>Contact probe</td>
</tr>
<tr>
<td>CICERO</td>
<td>Dental laboratory</td>
<td>Laser</td>
</tr>
<tr>
<td>Dux</td>
<td>Dental laboratory</td>
<td>Contact probe</td>
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<tr>
<td>Lava</td>
<td>Dental laboratory</td>
<td>Laser</td>
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<tr>
<td>Denti CAD</td>
<td>Dental laboratory</td>
<td>Contact probe</td>
</tr>
<tr>
<td>Everest</td>
<td>Dental laboratory</td>
<td>Optical scanner</td>
</tr>
</tbody>
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CEREC: Computer aided designing, CAM: Computer aided milling, CICERO: Computer integrated crown reconstruction
Reduced labor
The application of CAD/CAM technology reduces the labour cost and the chair side time. The total processing time is much shorter than that of conventional powder build-up and baking of porcelain. With regard to particular esthetic requirements, milled crowns could be completed merely by staining, using a conventional and simple method. The esthetic requirements can be more accurately met when compared to the conventional techniques.3,10

Cost effectiveness
Production of all-ceramic FPDs using a zirconia framework fabricated by a CAD/CAM process could provide even more financial benefits to owners of dental laboratories because they can invest in small measuring machines and not in large expensive facilities; thus they could concentrate on conventional porcelain processing.3,10

Quality control
Clinical and in vitro studies using finite element and fractographic analyses show that the primary causes of failure reported for all-ceramic FPDs differed from those reported for the metal-ceramic FPDs. Fractures of ceramic FPDs tended to occur in the connector areas because of the concentrated stress. Therefore, the design of the connector, particularly the dimensions, must be made independently depending on the type of ceramic material used for the framework. CAD better guarantees the durability and reduces the risk of fracture.28,29

DISCUSSION
Over the years there have been significant advancements in the field of dentistry and dental material sciences. Dentistry has evolved from crude restorations made of wires, ivory and wood to the current esthetic dentistry which involves use of high strength ceramics, dental implants and medical grade silicones for restoration of missing teeth and maxillofacial organs.3 Each advancement has marked a scope for newer and more esthetic restorative procedure. The current CAD-CAM technology being expensive is still making its place in the dental market. In the years to come the current CAD-CAM systems are expected to completely eliminate or markedly decrease the conventional all ceramic and porcelain fused to metal restoration fabrication techniques. CAD-CAM technology is expected to show more development and help in the fabrication of even more precise and esthetic restorations in future. CAD-CAM technology will contribute more efficiently in the fields of dental implantology and maxillofacial prosthodontics in the years to come. Enhancing a patient’s quality of life through dental service has become the most important factor. We have to offer more comfortable and higher quality dental services to all patients to maintain their oral function. A positive application of new materials and advanced technology is essential for dental service in the future. CAD/CAM technology will contribute greatly to the health of aging patients in future.

CONCLUSION
The advancements in the CAD-CAM systems have developed not only from the structural level but, also at the level of precision and applications. During the initial years when CAD-CAM was introduced in dentistry, their use was restricted to inlays, onlays and single unit crowns. Over the past few years CAD-CAM have shown and proved their utility in restorative, prosthetic, and pre-surgical dentistry. CAD-CAM technology is being constantly worked upon and it seems to have a more innovative and advanced future in the years to come.

REFERENCES


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