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# Development of CAD/CAM in Dentistry: A Review

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## Abstract

In 1971, Computer aided design/Computer aided manufacturing (CAD/CAM) technology was introduced in dentistry by Duret. Since then there has been a constant up gradation in the quality and popularity of its application to dentistry. Initially, prostheses fabricated using CAD/CAM technology were considered costly and technique sensitive, nowadays they are being extensively used because of advancements in various CAD/CAM systems that have gained popularity. CAD/CAM technology reduced the time and laboratory work for fabrication of prosthodontic prostheses. Today dental CAD/CAM systems are being used not only for fabrication of crowns and bridges, inlays and inlays but also for fabrication of removasble prosthesis, stents and dental implants. This paper reviews the evolution and development of the dental CAD/CAM systems in last three decades.

**Keywords:** CAD/CAM, Computer integrated crown, Construction

## 1. Introduction

Computer aided design/Computer aided manufacturing (CAD/CAM) technology has been revolutionized the dental industry since ever its introduction. However, due recent advancements in dental CAD/CAM technology, prosthesis can be fabricated directly from the data obtained from the patient's mouth. In current dentistry, CAD/CAM has not only for replacement of missing or coveted dentition, but also for the fabrication of maxillofacial prosthesis, for implant prosthesis and also for numerous researches.

## 2. Historical Background

However, Duret introduced the CAD/CAM technology in restorative dentistry in 1971 but the first restoration was manufactured using CAD/CAM in 1983. Initially, CAD/CAM technology was introduced in large industrial projects that has made their production easier and faster and was not popular as today due to 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.

However, in 1971, Duret used the numerically coordinated milling machine to mill the occlusal surface crown restoration using optical impression of abutment tooth and designed using functional movement but the Sopha system developed by Duret became a landmark in CAD/CAM dentistry (1,2).

In years 1979-80, Heitlinger, Rodder and Moermann worked continuously in development of dental CAD/CAM systems. Heitlinger and Rodder milled the stone to prepare crown, inlay or pontic whereas Moermann milled only the internal surface of inlay using single picture of the tooth preparation (4).

In 1987, Siemens Corporation developed the first ceramic reconstruction or CEREC 1 system. CEREC stands for "Chairside economical restoration of esthetic ceramic". It was a first of its kind and make possible to introduce ceramics in dentistry. Later in 1994, Siemens Corporation also developed CEREC 2 system but its third generation CEREC 3 system was developed by Sirona, Germany in 1999. The CEREC 3 system was first fully operational CAD/CAM system in clinical dentistry. CEREC 3 is improved version of CEREC 2 and has several technical improvements, including 3D camera, manipulation of picture, and grinding unit (5).

The next milestone in dental CAD/CAM was development of Procera system in 1987. Procera was designed by Dr. Anderson and developed by Nobal Parma Inc., Sweden. Initially, the fabrication titanium copings using by spark erosion was attempted by Dr. Anderson and later he introduced CAD/CAM technology for processing composite veneered restorations. Procera system was used for long time around the world for fabrication of all- ceramic frameworks. The current Procera system includes, electric discharge machine, and a coping and fabrication system with a pantograph (6).

DSC Dental, Switzerland, developed the Dux system, also kwon as Titan system. The Dux system consisted a precision contact digitizer sensor attached to computer and a milling machine. This system claims the milling process time about 10 minutes and accuracy in order of 30(±20) mm (7).

In 1990, The Celay system was developed by Mikrona Technologic, Switzerland. In a very small unit, Celay system 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 was developed by BEGO, Germany. This system was 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 transfers the digitize data of preparation tooth intra orally or using traditional models and die. The computer having software also controls the milling machine directly (7, 9, 10).

CICERO system was developed by CICERO Dental systems B.V., Netherland. CICERO stands for computer integrated crown reconstruction. This system consisted optical scanning unit and makes use of net-shaped metal, ceramic sintering and computer aided fabrication techniques (11). In 2002, Lava dental CAD/CAM system was introduced and it has been used for fabrication of zirconia framework in all ceramic restorations. Lava system consisted laser optical system to digitize the tooth preparation or dies (10, 12, 13).

The Cercon Zirconia system which is used to prepare zirconia based prostheses, was developed by Ceramco, USA. The impression of prepared abutment tooth sent to the laboratory, where it is transformed into a model. The wax pattern is prepared for each coping or crown using models. Each pattern is scanned and sent for milling (14, 15).

However, initially, implementation of CAD/CAM was focused on the fabrication of fixed restorations such as inlays, onlays, crowns and bridges. Scanning techniques were not able to differentiate the soft tissues and the interocclusal relationship was a drawback in fabrication of

partial and complete dentures but recent advancements in CAD/CAM technology have facilitated the dentistry to fabricate the partial and complete dentures.

In recent, CAD/CAM is also being used to fabricate the removable partial and complete denture frameworks. The Rapid prototyping technique has also been introduced for fabrication of the removable partial denture framework. The Rapid prototyping machine processes the standard tessellation language (STL) file (which is a stereolithographic image) by creating sliced layers of the model.

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

| CAD/CAM System | Type of production | Method of scanning |
|---|---|---|
| CEREC 1/2/3 | Direct in-office | Laser |
| Denticad | Direct in-office | Contact probe |
| Sopha | Direct in-office | Holography and Laser |
| Celey | Indirect in-office | Contact probe |
| Procera | Industrial outsourcing using netwok | Contact probe |
| CEREC In-Lab | Dental laboratory | Contact probe |
| CERCERO | Dental laboratory | Laser |
| Dux | Dental laboratory | Contact probe |
| LAVA | Dental laboratory | Laser |
| Denti CAD | Dental laboratory | Contact probe |
| Everest | Dental laboratory | Optical probe |
| | Dental laboratory | |

CAD: Computer aided designing, CAM: Computer aided milling, CICERO: Computer integrated crown reconstruction

## 3. Integrated Implantology

Nowadays, CAD/CAM systems are being implemented for fabrication of implant-supported prosthesis, as they have been used for the manufacturing of implant abutments and surgical stents in implant dentistry. (20) For better fit morphology, good form and emergence profile of abutment head should resemble a preparation tooth. To create optimal emergence profile, function, esthetics, and periodontal health implant position and appropriate preparation of hard and soft tissues is critical (21, 22). The main characteristics of CAD/CAM implant abutments are custom design, perfect fit and higher resistance. Computer aided surgery can be planned using CAD/CAM surgical templates (23-25).

The deferent of implant abutment can be classified into three groups:

1. Stock (prefabricated) abutments: Straight or preangled, available in different materials (titanium, zirconia) are milled using CAD/CAM technology.
2. UCLA (laboratory wax and cast) abutment: They are manufactured form gold platform and a castable sleeve that allows individualizing the shape and height.
3. Computer-milled solid abutments: A solid block of titanium is milled using a computerized milling machine to the operator's specifications.

In recent years, CAD/CAM has also been implemented in fabrication of maxillofacial prostheses using rapid prototyping procedure. Maxillofacial prostheses fabricated using CAD/CAM, are more accurate, shade matching and providing precise anatomic features.

## 4. CAD/CAM System Components and Procedure

The CAD/CAM system contains a scanning unit having a high resolution camera to read the finest details of the surface to be scanned. The scanned data stored into STL format sent to the CAD unit where CAD software designed it into desirable shape and geometry. The designed data then transferred to the milling unit that is attached to the computer, to mill the required prosthesis. The conventional prosthetic dentistry process follows preparation of abutment teeth, impression making followed by model preparation, wax up, and then casting but CAD/CAM technology involves digitization of abutment teeth direct from oral cavity and eradicate the conventional impression making process. CAD software is used to design the restoration based on digitized data that act as a virtual wax-up. The restorations are milled using a computer operated milling machine attached to the computer.

In recent, to counter the difficulty of accurately scanning the abutment teeth and adjacent teeth, after the impression, stone models are prepared and these stone models are scanned using scanning system and the STL image thus obtained is used for milling the prosthesis. The complete process of CAD designing and subsequent ceramic restoration milling using CAM requires about half an hour (3, 27).

## 5. Advantages of CAD/CAM Systems

CAD/CAM technology has been revolutionized the modern dentistry. Use of CAD/CAM takes following advantages over conventional practice.

***Application of new materials:***

However, advancements and development in material science has been provided several newer materials but using conventional techniques dental practice was limited to few materials. CAD/CAM technology provided the options of use of high strength, esthetic ceramics into current dental practice. Several other materials can also be practiced using CAD/CAM technology.

***Reduced labor:***

Use of CAD/CAM technology reduces the chair side time and laboratory labor. Total processing time for fabrication of dental prosthesis using CAD/CAM technology is much shorter than fabrication using conventional techniques. Use of CAD/CAM technology also reduces the clinical visits of patient.

***Cost effectiveness:***

Even two decades ago, gold was the popular material in dental industry but after the introduction of CAD/CAM technology, numerous high strength, esthetic and low cost materials are in practice. Use of CAD/CAM technology in fabrication process also eliminates the cost effective steps.

***Quality control:***

Implementation of CAD/CAM technology in dentistry provides options to analyze the quality of prosthesis using finite element and fractographic analyses. These processes not only reduce the failure rate but help to improve the quality of prosthesis. For example, in ceramic FPDs stress concentrated in connector areas hence fracture occur in this area. Therefore, appropriate dimensional design of the connector on CAD reduces the risk of fracture (28, 29).

## 7. Discussion

Over the years, dentistry and dental material science have been advanced significantly. Dentistry has been evolved from restorations made of wires, ivory and wood in ancient period to modern restorations, dental implants and maxillofacial organs. Advancement in dentistry creates scope for newer and more esthetic restorative process. A large area of dentistry industry is still using conventional techniques for fabrication of prostheses because of high initial expenses of dental CAD/CAM systems but in the years to come the current CAD-CAM systems are expected to completely eliminate or markedly decrease the conventional fabrication techniques. In future, more development is expected in CAD/CAM technology that will help in fabrication of more esthetic and even more precise restorations. It is also expected; the contribution of CAD/CAM technology in field of dental implantalogy and maxillofacial prothodontics will be more efficient in the coming years. Future of dentistry belongs to patient's comfort; hence we have to offer more comfort and higher quality dental services to all patients to maintain their oral health and function. An integrative application of advanced materials and technology is foundation for dental service in future. CAD/CAM technology will contribute greatly to the oral health of mankind in future.

## 8. Conclusion

The dental CAD/CAM systems have advanced not only in structural level development but, also at the level of precision and applications. In initial phase of dental CAD/CAM systems, their use was limited to inlays, onlays and single unit crowns. Over the past few years in dentistry, CAD/CAM technology proved its role restorative, prosthetic, and pre-surgical dentistry. The future of CAD/CAM technology in dentistry seems to have more advanced and innovative in the years to come.

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