CAD/CAM IN DENTAL RESTORATIONS: AN OVERVIEW

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ABSTRACT:

In the last two decades, exciting new developments in dental materials and computer technology have led to the success of dental computer aided design/computer aided manufacturing (CAD/CAM) technology. CAD/CAM is proving to be a valuable image enhancer, production booster and profit generator. Highly sophisticated chair side and laboratory CAD/CAM systems have been introduced. This article provides an overview of various CAD/CAM systems.

Key words :***CAD/CAM, Digitizing, Marginal integrity, Dental materials.***

INTRODUCTION

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 esthetic and durable restorations.

Brief history:

The major developments of dental CAD/CAM systems occurred in the 1980s. Dr. Duret was the first to develop dental CAD/CAM[1]. From 1971, he began to fabricate crowns with an optical impression of abutment followed by designing and milling. Later he developed Sopha system. Dr. Mormann developed CEREC System, an innovative approach to fabricate same day restorations at the chair side in the dental office [2]. Dr. Anderson developed Procera System [3] He attempted to fabricate titanium copings by spark erosion and introduced CAD/CAM technology into the process of composite veneered restorations [4]. This system later developed as a processing center networked with satellite digitizers around the world for the fabrication of all ceramic frameworks [5-13].

The CAD/ CAM process:

A CAD/CAM system utilizes a process chain consisting of scanning, designing and milling phases. The scanning device converts the shape of the prepared teeth into three dimensional (3-D) units of information (voxels). The computer translates this information into a 3-D map (point could). The operator designs a restoration shape using the computer which generates a tool path, which is used by the milling device to create the shape from a restorative material[12] .(Fig.1).

CAD/CAM Systems: (Table. 1)

Based on their production methods these systems can be divided into the following groups.

1. **In office system**: Most widely and commercially used in Cerec System. This system can scan the tooth preparation intraorally and by selecting appropriate materials, the dentist can fabricate the restorations and seat it within a single appointment.
2. **CAD/CAMS** – **Dental laboratory models**: The indirect systems scan a stone cast or die of the prepared tooth, in the dental lab (eg Cerec-in lab). Many of this system produce copings which require the dental technician to add esthetic porcelain for individualization and characterization of the restoration.
3. **CAD/CAM for outsourcing** dental lab work using networks: since the design and fabrication of the framework for high strength ceramics is technique sensitive, new technologies using CAD/CAM combined with network machining center that is outsourcing the framework fabrication using an internet have been introduced.

Table I : CAD/CAM systems by production method [12]
(I – Inlays; O - Onlays; C – Crowns; V – Veneers; *Cerec 2 and 3 only)

Production method	System	Scanning method	Restoration produced	Comments
Direct in-office	Cerec 1/2/3	Laser	Ceramic I/O/C*/V*	Most widely used
	Sopha	Laser & holography	Ceramic I/O/C/V	Lengthy design and manufacture
	Denticad	Contact probe	Ceramic I/O/C/V	Most automated
Indirect in-office/	Celay	Contact probe	Ceramic I/O/C/V	Copy milling only
Dental laboratory	Dux (Titan)	Contact probe	Titanium substructures	Requires aesthetic veneering
	Denti CAD	Contact probe	Ceramic I/O/C/V	Mills wide variety of materials
	Cerec in-Lab	Contact probe	Ceramic I/O/C/V	Requires lab stage
	Decim	Laser	Ceramic copings	Requires aesthetic veneering
	Cicero	Laser	Ceramic crowns	Built in veneering
	LAVA	Laser	Ceramic copings	Requires aesthetic veneering
	Everest	Optical scanner	Ceramic copings	Mills up to 16 units at once
Indirect industrial for outsourcing using networks	Procera	Contact probe	Ceramic copings	Requires aesthetic veneering

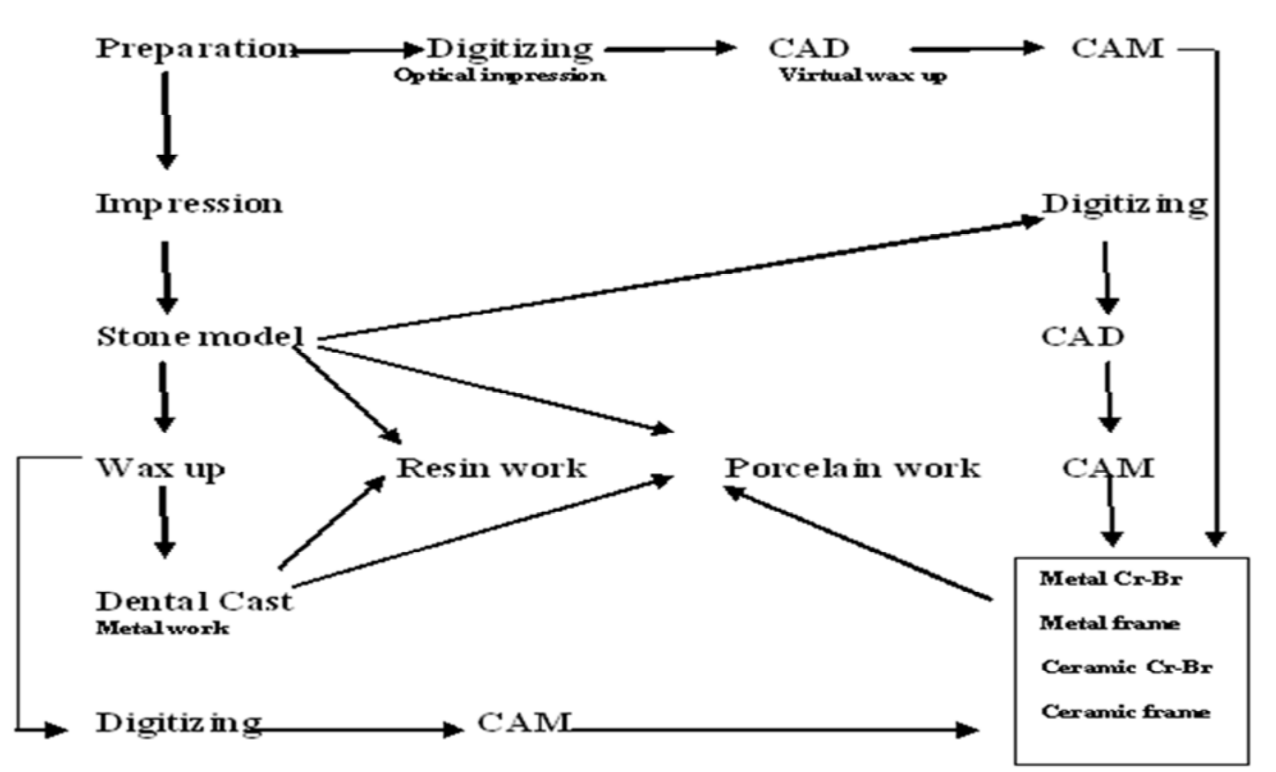

Fig.1. Overview of CAD/CAM Process.

Review of common CAD/CAM systems. (Fig. 2)

Cerec : An acronym for chair side economic reconstruction of esthetic ceramic Cerec* introduced in 1980s, improved cerec 2 introduced in 1996 and the advanced 3-D Cerec 3 in 2000. With Cerec 1 and Cerec 2, an optical scanner is used to scan the prepared tooth or impression and a 3-D image is generated on monitor. A milling unit is used to prepare the restoration. With newer Cerec 3-D, the operator records multiple images within seconds, enabling clinician to prepare multiple teeth in same quadrant and create a virtual cast for the entire quadrant. Designed restoration is transmitted to a remote milling unit for fabrication. Cerec in-lab is a lab system in which dies are laser scanned and image displayed on screen. After designing VITA In-cream blocks are used for milling. The coping is glass infiltrated and veneer porcelain added [8] In vitro evaluation of marginal adaptation of crown of cerec 3-D (47.5 µm $\pm$ 19.5 µm) was better compared with cerec 2 (97.0 $\pm$ 33.8 µm)[5].

DCS Precident: Comprises of a Preciscan laser Scanner and Precimill CAM multitool milling center. The DCS software automatically suggests, connector sizes and pontic forms for bridges. It can scan 14 dies simultaneously and mill up to 30 frameworks unit in one fully automated operation. It is one of the few systems that can mill titanium and fully dense sintered zirconia. An in vitro study showed that marginal discrepancies of alumina and ziroconia based posterior fixed partial denture machined by the DCS system was between 60 µm to 70µm [7]

Cercon: commonly referred to as a CAM system, it does not have a CAD component. The 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 with a low fusing, leucite free cercon Ceram to provide esthetic contour. Marginal adaptation for cercon all ceramic crowns and fixed partial dentures was reported 31.3 µm and 29.3 µm respectively. [9]

Procera All Ceram System[£]Introduced in 1994, it is the first system which provided outsourced fabrication using a network connection. Once the master die is scanned the 3-D images is transferred through an internet link to processing center where an enlarged die is milled by a computer controlled milling machines. This enlargement compensates for sintering shrinkage. Aluminum oxide powder is compacted on the die and coping is milled by a computer controlled milling machines. This enlargement compensates for sintering shrinkage. Aluminum oxide powder is compacted on the die and coping is milled before sintering at a very high temp (>1550°C). The coping is sent back to the lab for porcelain veneering. According to research data average marginal gap for Procera all Ceram restoration ranges from 54 µm to 64 µm [6].

CICERO system (computer integrated crown Reconstruction) Introduced by Denison et al in 1999, it includes optical scanning, metal and Ceramic sintering and computer assisted milling to obtain restoration. Basic reconstruction includes layered life like ceramic for natural esthetics, a precision milled occlusal surface and a machined high strength ceramic core[11]. The aim of CICERO is to mass produce ceramic restoration at one integrated site. It includes rapid custom fabrication of high strength alumina coping and semi finished crowns to be delivered to dental laboratories for porcelain layering / finishing.

Lava CAD/CAM System[2]# Introduced in 2002, used for fabrication of zirconia framework for all ceramic restorations. This system uses yttria stabilized tetragonal zirconia poly crystals (Y-TZP) which have greater fracture resistance than conventional ceramics. Lava system uses a laser optical system to digitize information. The Lava CAD software automatically finds the margin and suggests a pontic. CAM produces an enlarged framework to compensate shrinkage. A partially sintered ziroconia block is selected for milling. Milled framework undergoes sintering to attain final dimensions, density and strength. 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 $\pm$ 25 µm Vs 59 $\pm$ 21 µm) [10]

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£Nobel Biocare, USA, INC, Yorba Linda, California.

#3M ESPE, St. Paul, Minnesota

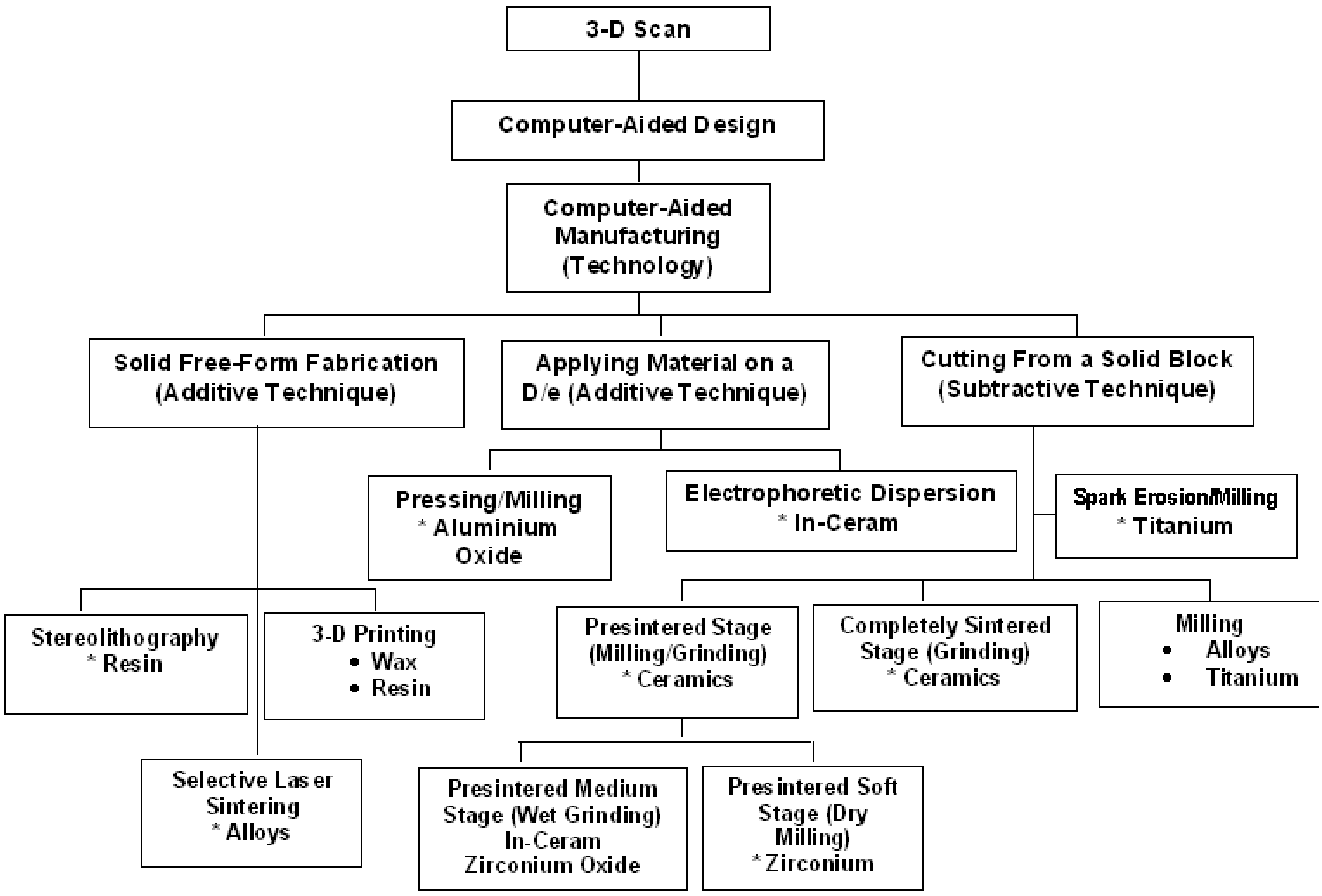

Fig. 2 . Overview of CAD/CAM manufacturing systems for Dentistry

Materials

The combination of materials that can be used and restoration types that can be produced vary with different systems. Some CAD/CAM systems can fabricate a final restoration with some materials with acceptable strength and esthetics while others require subsequent veneering to achieve acceptable esthetics. Materials used with different CAD/CAM systems are shown in Table 2.

CONCLUSION

CAD/CAM systems offer automation of fabrication procedures with standardized 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 materials with outstanding biocompatibility combined with adequate mechanical strength, provisions for esthetic 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. Patient's expectations, financial constrain, operator's preference, as well as availability of CAD/CAM systems will dictate the suitability of this type of restorations on an individual basis in the future. Innovations will continue to affect and challenge dentistry.

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TABLE II. CAD/CAM and copy-Milled Ceramics Used for All-Ceramic Prostheses [14,15]

CERAMIC BLOCK	CERAMIC TYPE	CERAMIC VENEER	INDICATIONS	MANUFACTURER
CerAdapt	Highly sintered Al_2O_3	All Cream	Implant Superstructure	Nobel Biocare
Cercon Base	Presintered ZrO2; postsintered after milling	Cercon Ceram S	Crowns and FPDs	Dentsply Ceramco
DC-Kristall	Leucite-based	Triceram	Crowns	DCS Dental AG/Esprident
DC-Zirkon	Presintered ZrO_2; hot isostatic post compaction	Vitadur D Triceram	Crowns and FPDs	DCS Dental AG/Vita/Esprident
Denzir	Presintered ZrO_2; hot isostatic post compaction	Empress2	Crowns and FPDs	Decim, Ivoclar
LAVA Frame	ZrO_2; presintered and post sintered	LAVA Ceram	Crowns and FPDs	3M ESPE
ProCad	Leucite-based	Maltechnik	Veneers, inlays, onlays, and crowns	Ivoclar
Procera All Ceram	Al_2O_3; presintered and postisintered	All Ceram	Crowns and FPDs	Nobel Biocare
Synthoceram	Al_2O_3 reinforced; pressed and post sintered	Sintagon	Crowns	Elephant
VitaBlocs Mark II	Feldspathic porcelain block	Maltechink	Veneers, inlays, onlays and crowns	Vident
Vita Blocs Alumina	Sintered Al_2O_3; followed by glass infiltration	Vitadur Alpha	Crowns and FPDs	Vident
Vita Blocs Spinell	Sintered MgO-Al_2O_3 spinel followed by glass infiltration	Vitadur Alpha	Crowns	Vident
Vita Blocs Zirconia	Sintered Al_2O_3/ZrO_2 followed by glass infiltration	Vitadur Alpha	Crowns and FPDs	Vident
Zircagon	ZrO_2; presintered and post sintered	Zircagon	Crowns	Elephant

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