

Assessment of Chair-side Computer-Aided Design and Computer-Aided Manufacturing Restorations: A Review of the Literature

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Abstract:

Background: This paper aimed to evaluate the application of computer-aided design and computer-aided manufacturing (CAD-CAM) technology and the factors that affect the survival of restorations.

Materials and Methods: A thorough literature search using PubMed, Medline, Embase, Science Direct, Wiley Online Library and Grey literature were performed from the year 2004 up to June 2014. Only relevant research was considered.

Results: The use of chair-side CAD/CAM systems is promising in all dental branches in terms of minimizing time and effort made by dentists, technicians and patients for restoring and maintaining patient oral function and aesthetic, while providing high quality outcome.

Conclusion: The way of producing and placing the restorations made with the chair-side CAD/CAM (CEREC and E4D) devices is better than restorations made by conventional laboratory procedures.

Key Words: chair-side restoration, computer-aided design and computer-aided manufacturing, digital dentistry

Introduction

The idiom "CAD/CAM" in dental technology is an abbreviation for "computer-aided design" and "computer-aided manufacturing," used to improve the design and creation of dental restorations including crowns, veneers, inlays and onlays, fixed bridges, implants, dentures, and orthodontic appliances. Early efforts of this technology were in the mid-1980s. Dr. Mörmann developed CEREC system; an innovative approach to make same day restorations in the dental clinic at the chair-side.¹ Historically, the CEREC System (Sirona) was the first chair-side CAD/CAM system in dentistry and is currently available in its third product generation. In 2006, Mörmann pointed out that the concept

of CEREC CAD/CAM is becoming an important part of dentistry.²

CAD/CAM Components

The CAD/CAM systems consist of three major components. The first component is a digitalization tool/scanner, which converts geometry to digital information that can be processed by the computer. The second component is software, which processes information, depending on the application, provides information and data of the product intends to manufacture. The third component is a milling device/production technology that converts the information into the specific product.²

CAD/CAM Systems

The available advanced CAD/CAM systems can be divided into the following three groups based on their production methods:³

- In office system: Where a dentist digitally scans the prepared tooth, creates restorations chair-side, and then seats it within a single appointment.
- In lab system: Where laboratories could scan models made from physical impressions and use CAD/CAM to produce restorations.
- Centralized production: Where a dentist captures chair-side digital impressions then sent data via the internet to the laboratory.

The current existing in-office systems with chair-side milling machines are the CEREC from (Sirona Dental; Charlotte, NC) and E4D from (D4D Technologies; Richardson, TX). Chair-side digital impression systems with transfer of images to the laboratory include the iTero, CEREC and Lava C.O.S. systems. The scanned data can be exported to a laboratory (via CEREC AC Connect or E4D Sky) to have more complicated or advanced restorations fabricated.³

Chair-side CAD/CAM Materials

Several of materials are available for chair-side CAD/CAM restorations, which achieved predictability and longevity. All blocks are either monochromatic or polychromatic form for chair-side CAD/CAM restorations. Studies have proved their predictability and longevity. These materials include esthetic and high-strength ceramics, composite resins, and nanoceramics, which facilitate handling and finishing. Innovations in the CEREC AC system involving the use of

materials such as IPS Empress CAD Multi Block and IPS e.max CAD have provided dentists with an efficient and effective delivery style for the routine placement of all-ceramic restorations chair-side.⁴

- Feldspar-based ceramic Vitablocs Mark I (Vident).
- High-glass-feldspar-based ceramic Vitablocs Mark II (Vident).
- Infiltrated leucite glass-ceramic. ProCAD (Ivoclar Vivadent).
- Resin-based composite Paradigm MZ100 blocks (3M ESPE).
- Paradigm C (3M ESPE).
- Lithium disilicate glass ceramic (IPS e.max CAD, Ivoclar Vivadent) for anterior or posterior crowns, implant crowns, inlays, and onlays or veneers.
- CEREC block by Sirona.

These blocks material have strength, dense, high-quality, and excellent esthetic properties superior than traditional material as well these materials exhibit a “chameleon” effect. All recent developments in CAD/CAM materials concern high strength and easy-to-use. The Computer-aided manufacturing procedures will indisputably change many aspects of dentistry in the future, especially with regard to treatment simplicity and production period. Therefore clinicians and technicians must be aware of the advantages and disadvantages of computer-aided manufacturing while such procedures continue to develop and become an integral part of dentistry.⁵

System development

The CEREC system developed through a combination of software and hardware upgrades since its launch to the dental marketplace as the CEREC 1 system led to a marked improvement in clinical efficiency through allowing for simultaneous design of one restoration while milling a second one. Three-dimensional (3D) design program improved speed and memory of computers, and also improved the clinical workflows of chair-side system.⁵

New CEREC Omnicam is powder-free and precise 3D continuous images in natural color. CAD/CAM-generated all-ceramic restorations facilitate the rebuilding of deeply destructed teeth regardless of the location of the cavity margins.⁶

Advantages

Providing a tooth-colored restoration in single visit appointment is the main goal of the chair-side concept with CAD/CAM technology. This system is an advantage for the immediately definitive protection of the tooth without any temporary phase. In-office CAD/CAM allows dentists to provide same-visit indirect restorations that are accurate and esthetically satisfied. Digital impression taking create accurate models, which is used for fabrication of either traditional or CAD/CAM restorations, and needs less chair-side time.³

In-office CAD/CAM systems offer the amazing and distinctive features that give the dentist full control over restorative process; dentist will appreciate the speed of these systems in addition to the significant reduction in lab bills. Chair-side CEREC CAD/CAM is designed to eliminate the need for traditional impression and provisional restorations. The preparation and margin evaluation was performed immediately. Van Zeghbroeck *et al.* (2012) reported that using the CEREC 3D chair-side CAD/CAM technology shown to be a feasible, precise, esthetic and durable solution in limited cognitive skills patient.⁷ Most patients prefer the CAD/CAM single-appointment concept to the conventional multi-appointment.⁸ The dentist could produce restorations use of digital impressions with a high degree of reliability and longevity.⁹

Touchstone *et al.* (2010) intensified the smile of a 63-year-old woman that was concerned about the appearance of her existing dental restorations using milled CAD/CAM all-ceramic polyolithic restorations. Conclude that digital restorative dentistry has matured. Although previously it was restricted to the chair-side single-visit treatment, now can be utilized to almost any restorative conditions, including rehabilitation of full-mouth.¹⁰

CEREC restorations have an acceptable, marginal adaptation and clinical longevity along with reduced chair time and improved esthetics.¹¹ CAD/CAM technologies give dentist The ability to fabricate an chair-side restoration with controlling all of the essential elements of a restoration—from contours and occlusion to finishing and choice of placement—within timetables that are correspond with those of conventional methods.⁴

Disadvantages

Despite of the previous advantages of chair-side CAD/CAM system we can concludes the disadvantage of this system include cost, the price of investment and maintenance, fear of the unknown, lack of willingness to learn a new concept, refuse of change practicing way, dentists should have additional training in CAD/CAM, negative comments from some peers, the few number of users, reject things that would reduce the stability of the practice, the size of the scanning device and the milling machine, lack of desire to delegate clinical procedures, relationship with previous dental laboratories, concern about color matching, staining, quality and longevity of restorations.¹¹

Application of CAD-CAM technology

Beside its most common application in the restorative treatments (inlay-onlay-crown-veneer-multi units FPD), application of the CAD/CAM technology was performed in Orthodontic occlusal splints, in implant related components,¹² and orthodontic treatment planning to measure soft tissues,¹³ in addition to fabrication of removable complete denture even

if the development was slowly.¹⁴ Furthermore, CAD/CAM technique is ideal for fabrication of oral and facial prostheses.¹⁵

It is a feasible solution in limited cognitive skills patient.⁷ CAD/CAM-generated all-ceramic restorations facilitate the rebuilding of deeply destructed teeth regardless of the location of the cavity margins.⁶

The aim of the study

The main objective of this paper was to review the chair-side CAD/CAM clinical performance. The author's reviewed all valid research material related chair-side CAD/CAM from a database of articles available from 2004 up to 2014. Data sources included PubMed, Medline, Embase, Science Direct and Wiley Online Library. Only relevant literature was considered. This paper gives an in depth insight on chair-side CAD/CAM clinical performance. It gives clinicians a detailed understanding of the advantages, drawbacks, indications, contraindications of chair-side CAD/CAM. Clinicians are able to correlate this knowledge during case selection and placement for better longevity and performance of restorations.

Discussion

Material comparison

Numerous studies compared the materials used in chair-side CAD/CAM system (Table 1). Magne *et al.* (2010) studied fatigue resistance of CAD/CAM composite resin and ceramic posterior occlusal veneers found that composite resin (Paradigm MZ100) had significantly higher fatigue resistance ($P < 0.002$) compared to IPS Empress CAD and IPS e.max CAD¹⁶ where Schlichting *et al.* (2011) found that composite resins (MZ100 and XR) increased the fatigue resistance of ultra-thin occlusal veneers ($P < 0.001$) if compared to the ceramics evaluated (Empress CAD and e.max CAD).¹⁷ Vichi *et al.* (2013) Stated that materials available on the market for CEREC CAD/CAM, had a flexural strength greater than 100 Mpa, therefore, meets the ISO standard.¹⁸

In 2014 researchers, studied the fracture resistance of a CAD/CAM Resin Nano Ceramic and a CAD ceramic at

different thicknesses above 0.5 mm which could afford the normal bite force.¹⁹ Batson *et al.*, 2014 reported that CAD/CAM-generated restorations for posterior teeth fabricated from variant materials had acceptable clinical outcomes.²⁰

Survival and success

According to scientific literature, they reported success rates for CAD/CAM produced inlays of 90% after 10 years and 85% after 12 and 16 years.²¹ The survival of CEREC-generated restorations was reported to be about 97 for 5 years and 90% for 10 years.⁹

Digital impressions and conventional impressions

Many studies investigated digital impressions and conventional impression techniques (Table 2). Digital impression involve taking a digital scan with an intraoral camera of prepared tooth and surrounding soft tissue, the software translate this data into a virtual 3D model instead of die in order to design then mill the restoration, without any need of impression materials, trays, pouring and trimming. This procedure enables immediate evaluation of preparation and margin.⁴

Digital imaging has been constantly improved. CEREC has presented the bluecam with anti-shake features and automatically eliminates any substandard images, which require a light dusting of powder to make imaging easier. In 2012, Sirona introduced the new powder-free CEREC Omnicam, which displaying the 3D data in full color. CAD/CAM images can be taken either through direct or indirect imaging. In The indirect systems, we obtained the digitalization from the impression material or cast, where the direct way the image is taken directly from the mouth using intraoral scanners. In other words, a virtual 3D model is created on the bases of three sets of data (stone cast, impression body, and intraoral) obtained from the scanning process. Digital impressions offer speed, efficiency, ability of storing captured information indefinitely, transferring digital images between the dental office and the laboratory and less invasive than the traditional way.²² Seelbach *et al.* (2013) stated that digital impression systems allow fabricating restorations with similar accuracy to conventional impression methods.²³

Table 1: The studies that compared the materials used in chair-side CAD/CAM system.

Year+first author+reference	Technique	Test variable	Conclusion
2010, Magne <i>et al.</i> , ¹⁶	CAD/CAM composite resin and ceramic	Fatigue resistance	Composite resin (Paradigm MZ100) had significantly higher fatigue resistance ($P < 0.002$) compared to IPS Empress CAD and IPS e.max CAD
2010, Schlichting <i>et al.</i> , ¹⁷	Ultra-thin CAD/CAM composite resin and ceramic	Fatigue resistance	Composite resins (MZ100 and XR) increased the fatigue resistance of ultra-thin occlusal veneers ($P < 0.001$) if compared to the ceramics evaluated (Empress CAD and e.max CAD)
2013, Vichi <i>et al.</i> , ¹⁸	-	-	Materials available on the market for CEREC CAD/CAM, had a flexural strength greater than 100 MPa, therefore, meets the ISO standard
2014, Chen <i>et al.</i> , ¹⁹	CAD/CAM RNC and a CAD ceramic	Fracture resistance at different thicknesses	The thickness above 0.5 mm could afford the normal bite force
2014, Batson <i>et al.</i> , ²⁰	CAD/CAM fabricated posterior restorations with different technologies	Restoration quality of and gingival response	CAD/CAM-generated restorations for posterior teeth fabricated from variant materials had acceptable clinical outcomes

RNC: Resin nano ceramic, CAD: Computer-aided design, CAM: Computer-aided manufacturing, CEREC: Chair-side CAD/CAM

Table 2: The studies that investigated digital impressions and conventional impressions technique.

Year+first author+reference	Technique	Test variable	Conclusion
2014, Svanborg <i>et al.</i> , ²⁷	Digital and conventional impressions	Marginal and internal fit	The digital impression technique is more accurately and can generate 3-unit FDPs with a significantly closer fit in comparison with the VPS technique
2014, Yuzbasioglu <i>et al.</i> , ²⁴	Digital and conventional impression	Patients' treatment comfort, effectiveness, and clinical outcomes	Digital impressions led to more time-efficient than traditional impressions. Patients preferred the digital impression method instead of the traditional one
2014, Ender <i>et al.</i> , ²⁵	Conventional and digital methods	Accuracy of conventional and digital impression	Digital impression systems show higher local deviations of the full-arch model, but they offer excellent clinical results within their indications applying the right scanning technique
2014, Svanborg <i>et al.</i> , ²⁷	Digital and conventional impressions	Marginal and internal fit	The digital impression technique is more accurately and can generate 3-unit FDPs with a significantly closer fit in comparison with the VPS technique
2013, Lee <i>et al.</i> , ²⁶	Conventional and digital impression	Dental student and the clinician perception	Traditional impression was more difficult to conduct for the student than the clinician. The digital impression is the most effective impression technique
2013, Seelbach <i>et al.</i> , ²³	Digital and conventional impression	Accuracy of digital and conventional impression	Digital impression systems allow fabricating restorations with similar accuracy to conventional impression methods
2012, Galhano <i>et al.</i> , ²²	CAD-CAM restorations	Optical impression systems	Digital impressions offer speed, efficiency, ability of storing captured information indefinitely, and less invasive than the traditional way
2010, Poticny <i>et al.</i> , ⁴	In-office CAD/CAM	Predictable and esthetic outcomes	The digital impression procedure enables immediate evaluation of preparation and margin

CAD: Computer-aided design, CAM: Computer-aided manufacturing

Yuzbasioglu *et al.* (2014) Found that digital impressions are more efficient in minimize the time from the traditional impressions. Patients prefer digital impression technology instead of traditional techniques. They compare two impression techniques from the standpoint of patient predilection and treatment comfort. They found that Digital impressions led to more time-efficient than traditional impressions. Patients preferred the digital impression method instead of the traditional one.²⁴ Ender and Mehl (2014) found that traditional and digital impression methods reveal differences relating full-arch accuracy. Digital impression systems show higher local deviations of the full-arch model, but they offer excellent clinical results within their indications applying the right scanning technique.²⁵

Lee *et al.* (2013) assessed the level of difficulty and cognition between dental students and experienced clinicians when submitting digital and traditional impressions. They found that traditional impression was more difficult to conduct for the student than the clinician; nevertheless, the difficulty level of the digital impression was the same in both of them; while the student preferred the digital impression as the most effective impression technique, and the clinician had an even distribution in the choice of preferred and effective impression techniques.²⁶ In 2014, Svanborg *et al.*, stated that the digital impression technique is more accurately and can generate 3-unit FDPs with a significantly closer fit in comparison with the VPS technique.²⁷

Comparison of chair-side systems CEREC and E4D

The researchers found that Lithium disilicate crowns manufactured with the CEREC 3D Bluecam scanner CAD/CAM system or the heat-pressing technique has shown a significantly minimum vertical misfit than crowns manufactured with E4D Laser scanner CAD/CAM system.²⁸ Other researcher pointed out that spacer thickness and

manufacturing technique affecting the adaptation of ceramic crowns while the heat-press achieved the best marginal and internal crown adaptation outcomes. They recommended 30- or 60- μ m spacer thickness for the E4D CAD/CAM system.²⁹

Clinical performance of chair-side CAD/CAM restoration

Numerous studies investigated the clinical performance of chair-side CAD/CAM restorations (Table 3). Song *et al.* (2013) reported that the marginal gaps of anterior 3-unit zirconia FPD varied in accordance with CAD/CAM systems, but still within clinically acceptable limits in comparison with traditional metal-ceramic restoration.³⁰

Kohorst *et al.* (2009) concluded that the marginal fit of zirconia FDPs is significantly dependent on the CAD/CAM system used with restorations processed of fully sintered zirconia showing better fitting accuracy.³¹ Guess *et al.* (2009) found that pressed ceramic and CAD/CAM fabricated partial coverage restorations showed a reliable treatment option to restore larger distortions in posterior teeth. Marginal degradation of the resin cement and deterioration of the all-ceramic materials during clinical function determine the clinical long-term performance of partial coverage restorations.³²

Romeo *et al.* (2009) concluded that marginal fit of CAD/CAM restoration is acceptable clinically and within the limits consideration of ADA specification #8. Hence, milled CAD/CAM crowns can be considered a good alternative for the conventional waxing-investing-casting technique.³³

Tsitrou and van Noort (2008) showed that in the minimal preparation only the composite material produced acceptable crowns with intact margins, as ceramic materials required a wider preparation design in order to produce acceptable crowns. It was also found that the materials' properties, the

Table 3: The studies that investigated the clinical performance of chair-side CAD/CAM restorations.

Year+first author+reference	Technique	Test variable	Conclusion
2014, Silva <i>et al.</i> , ⁴⁰	Digital and conventional impressions.=	Marginal and internal fit	Restorations fabricated from digital impression demonstrate better internal fit than those fabricated from conventional impression
2014, Keul <i>et al.</i> , ⁴³	Chair-side and lab side digitalization	Marginal fit accuracy	The direct digitalization showed significantly higher "trueness" than indirect digitalization
2014, Yuzbasioglu <i>et al.</i> , ²⁴	Digital and conventional impression	Patients' treatment comfort, effectiveness, and clinical outcomes	Digital impressions resulted in a more time-efficient technique than conventional impressions. Patients preferred the digital impression technique rather than conventional techniques
2014, Tidehag <i>et al.</i> , ⁴¹	In-office optical scanning	Accuracy of ceramic restorations	Marginal and internal accuracy of in-office CAD/CAM ceramic restorations is on the same level as that of conventional hot-pressed glass-ceramic restorations
2014, Neves <i>et al.</i> , ²⁸	Chair-side CAD/CAM systems or the heat-pressing technique	Marginal fit	Lithium disilicate crowns manufactured with the CEREC 3D Bluecam scanner CAD/CAM system or the heat-pressing technique has shown a significantly minimum vertical misfit than crowns manufactured with E4D Laser scanner CAD/CAM
2014, Mously <i>et al.</i> , ²⁹	CAD/CAM technology and the heat-press technique	Marginal and internal adaptation	They recommended 30 µm or 60 µm spacer thickness for the E4D CAD/CAM system
2014, Euán <i>et al.</i> , ⁴⁷	CAD/CAM system	Marginal adaptation and the finish line design	Restorations fabricated with the lava chair-side oral scanner displayed smaller marginal gaps than those made with the lava all-ceramic system
2014, Arocha <i>et al.</i> , ⁵²	CAD/CAM composites	Color stainability	CAD/CAM composites immersed in staining solutions showed less-color stability when compared to traditional laboratory-processed resin composites
2014, Salameh <i>et al.</i> , ⁵³	CAD/CAM system	Color and translucency	The shade match of CAD/CAM porcelain veneers was not affected by the translucency of used milling block or the opacity of the resin cement
2014, Bosch <i>et al.</i> , ⁵⁴	CAD/CAM milling processes	Accuracy analysis	Restorations milled with a 5-axial milling unit have a higher exactness than those milled with a 4-axial milling unit
2014, Zamboni <i>et al.</i> , ⁵¹	CAD/CAM technique.	Mechanical load and cuspal deflection	The cuspal deflection increased only in the CAD/CAM technique
2014, Tamim <i>et al.</i> , ⁴⁶	Intraoral digital impressions	Marginal integrity	Clinical evaluation of the marginal integrity presented satisfactory outcomes according to the CDA criteria
2014, Reich <i>et al.</i> , ⁵⁶	CAD/CAM-generated lithium disilicate	Complication and failure	Record failure-free rate and complication-free rate were revealed as 93 and 83%, respectively
2014, Alaghemand <i>et al.</i> , ⁶²	CAD/CAM ceramic inlays	Microleakage and thickness of resin cement	CAD/CAM inlays had less cement thickness than laboratory-made inlays, but this was not related to their microleakage
2013, Reich <i>et al.</i> , ⁵⁷	Chair-side generated crowns	Complications and clinical performance	The clinical performance of the crowns was exactly satisfying
2013, Song <i>et al.</i> , ³⁰	Different CAD/CAM systems	Marginal fit	The marginal gaps of anterior 3-unit zirconia, FPD varied in accordance with CAD/CAM systems
2013, Seelbach <i>et al.</i> , ²³	Digital and conventional impression	Accuracy of digital and conventional impression	Digital impression systems allow fabricating restorations with similar accuracy to conventional impression methods
2013, Yildiz <i>et al.</i> , ³⁶	Manually and CAD/CAM onlays	Fracture resistance	The fracture resistance of CAD/CAM onlays was significantly lower than that of pressable ceramics
2012, Kassem <i>et al.</i> , ⁶⁴	CAD/CAM ceramic and composite molar crowns	Fatigue resistance	Composite crowns were more fatigue-resistant than ceramic crowns. Cement type had a significant effect on fatigue resistance of the ceramic crowns but not the composite ones
2012, Dong <i>et al.</i> , ⁶³	Chair-side CEREC CAD/CAM ceramic	Cementation and fracture toughness	A thinner film of cementation is recommended for chair-side CAD/CAM ceramic restoration
2012, Alghazzawi <i>et al.</i> , ⁴²	CAD/CAM different fabrication steps	Marginal adaptation	Ceramic crown manufactured by CAD/CAM system have an adequate marginal fit
2012, Miyazaki <i>et al.</i> , ⁴⁴	CAD/CAM systems	The accuracy	The accuracy of a prosthesis using CAD/CAM is affected by the scanning procedures, software design procedures, milling procedures and shrinkage effects
2012, Renne <i>et al.</i> , ⁴⁸	CAD/CAM crowns	Marginal fit and preparation errors	The preparation quality has a significant effect on marginal gap of CAD/CAM crowns
2010, Fasbinder <i>et al.</i> , ³⁸	CAD/CAM crowns	Clinical evaluation	Lithium disilicate crowns have good performance after 2 years of clinical service
2010, Reich <i>et al.</i> , ⁵⁵	CAD/CAM crowns	Clinical performance	The crowns revealed clinically satisfying results
2010, Tsiitrou <i>et al.</i> , ³⁵	minimally prepared resin bonded CAD/CAM crowns	Structural integrity and fracture status	Minimally invasive prepared resin bonded CEREC crowns showed equal fracture resistance and pattern of fracture to that of crowns bonded to traditionally prepared teeth
2009, Wittneben <i>et al.</i> , ⁵⁸	CAD/CAM single-tooth restorations	Clinical performance	Long-term survival rates for CAD/CAM single-tooth restorations appear to be similar to traditional ones
2009, Kohorst <i>et al.</i> , ³¹	Different CAD/CAM systems	Marginal accuracy	The marginal fit of zirconia FDPs is significantly dependent on the CAD/CAM system used with restorations processed
2009, Guess <i>et al.</i> , ³²	Pressed ceramic and CAD/CAM restorations	Survival rate	Marginal degradation of resin cements and deterioration of all - ceramic materials during clinical function determine the long-term performance of partial coverage restorations
2009, Romeo <i>et al.</i> , ³³	Full-coverage CAD/CAM restorations	Marginal adaptation	Marginal fit of CAD/CAM restoration is acceptable clinically and within the limits consideration of ADA specification #8

contd...

Table 3: Contd...

Year+first author+reference	Technique	Test variable	Conclusion
2009, D'Arcy <i>et al.</i> , ³⁷	CEREC 3D CAD/CAM all-ceramic crowns	Reproducibility and exactness of internal fit	No statistics differences between the mean thickness of the Marginal Gap, the Axio-Occlusal Transition Gap and the Occlusal Gap present consistency of the exactness of fit
2008, Tsitrou <i>et al.</i> , ³⁴	Cerec system	Minimal preparation designs	The materials' properties, the milling mode, and cutting instruments are determining factors in establishing the extent of the minimal preparation
2008, Otto <i>et al.</i> , ⁵⁹	Chair-side CEREC CAD/CAM inlay and onlay	Long-term clinical results	The survival rate was 88.7% after up to 17 years of clinical service for CEREC CAD/CAM restorations considered very respectable clinical result
2006, Fasbinder ⁹	CAD/CAM restorations	Clinical performance	The CEREC-generated restorations survival probability was approximately 97% for 5 years and 90% for 10 years
2006, Attia <i>et al.</i> , ⁶¹	Composite resin and feldspathic all-ceramic CAD/CAM crowns	Fracture load	The cyclic loading fatigue significantly decreases the fracture loads of composite resin and all-ceramic crowns, while adhesive cementation significantly expanded the fracture loads
2005, Wiedhahn <i>et al.</i> , ⁶⁰	Cerec veneers	Long-term evaluation	CAD/CAM generated porcelain laminate veneers may present good clinical results and longevity as traditional ones
2004, Sjögren <i>et al.</i> , ²¹	CAD/CAM-(Cerec) ceramic inlays	Performance of Cerec inlays	Patient satisfaction of the Cerec inlays were high and the performance was acceptable

CAD: Computer-aided design, CAM: Computer-aided manufacturing, FPD: Fixed Partial Denture

milling mode, and cutting instruments are determining factors in establishing the extent of the minimal preparation.³⁴

Tsitrou *et al.* (2010) compared the structural integrity and fracture status of teeth prepared traditionally and minimally invasive to restore with resin bonded CAD/CAM crowns manufacture from one material, they found that minimally invasive prepared resin bonded CEREC crowns showed equal fracture resistance and pattern of fracture to that of crowns bonded to traditionally prepared teeth.³⁵ Others evaluated fracture resistance in lithium disilicate onlays fabricated manually and with CAD/CAM technique, yielded that both can be a viable treatment option.³⁶

D'Arcy *et al.* (2009) assess the reproducibility and exactness of internal fit using CEREC 3D CAD/CAM all-ceramic crowns and study the proximal contact point areas between the crowns and adjacent teeth. They didn't found any statistics differences between the mean thickness of the marginal gap, the axio-occlusal transition gap, and the occlusal Gap.³⁷

Seelbach *et al.* (2013) stated that digital impression systems allow the manufacturing of restorations with a similar exactness as traditional impression techniques.²³ Sjögren *et al.* (2004) reported high patient gratification and espousal of the CEREC inlays, and the performance after 10 years of clinical service was satisfactory, particularly with regard to the inlays luted with the chemically cured resin composite. The characteristics of the luting agents influence the longevity of ceramic inlays.²¹

Fasbinder (2006) reported that postoperative sensitivity was principally due to occlusal interferences. Long-term postoperative sensitivity was not a reported problem. Restoration fracture is the primary mode of failure for CEREC-generated restorations and similar to other ceramic restorations. Margin wear was seldom reported. The survival possibility of CEREC-generated restorations was reported

to be about 97% for 5 years and 90% for 10 years. Low rate of restoration fracture and long-term clinical survive ability document the effectiveness of the CEREC system as a reliable, esthetic restorative option for patients.⁹ In 2010, Fasbinder *et al.* pointed out that there was no reported sensitivity at 1 or 2 years.³⁸

Nash (2014) made resurfacing for a natural tooth structure using ceramic laminates in order to solve different aesthetic and/or functional troubles, expected that CAD/CAM ceramic laminates can be last about twice as long as direct composite alternatives, making them an excellent patient treatment option, when indicated.³⁹

Silva *et al.* (2014) indicated that restorations fabricated from digital impression demonstrate better internal fit than those fabricated from conventional impression.⁴⁰ In 2014, they found slight differences between the two types of ceramic crowns (CAD/CAM ceramic crowns-conventional hot-pressed glass ceramic crown) with regard to the internal fit.⁴¹ Ceramic crown manufactured by CAD/CAM system have an adequate marginal fit, and the process of glass infiltration improves the marginal fit after machining.⁴²

Keul *et al.* (2014) stated that regarding the accuracy, which leads to better marginal fit the direct digitalization showed significantly higher "trueness" than indirect digitalization.⁴³ The accuracy of a prosthesis using CAD/CAM is affected by the scanning procedures, software design procedures, milling procedures and shrinkage effects.⁴⁴ Accuracy has been recorded for intra-oral scanners by several authors.⁴⁵

Tidehag *et al.* (2014) concluded that marginal and internal accuracy of in-office CAD/CAM ceramic restorations is on the same level as that of conventional hot-pressed glass-ceramic restorations.⁴¹ Clinical assessment of the marginal integrity showed satisfactory outcomes according to the CDA criteria.⁴⁶

Some researchers identified differences in the finish line design were only between the round shoulder and chamfer with the lava all-ceramic system. In another hand, restorations fabricated with the lava chair-side oral scanner showed smaller marginal gaps.⁴⁷ The preparation quality has a significant effect on marginal gap of CAD/CAM crowns.⁴⁸

The rounded shoulder finish line show marginal discrepancy values significantly lower than tilted and large chamfer, but large chamfer produced the least internal discrepancy values. Independent of the finish line type, internal discrepancy was the lowest in the axial region followed by the radius and occlusal regions.⁴⁹ Euán *et al.* (2012) stated that marginal adaptation was affected by the finish line design. The marginal gap was within the scope of clinical acceptability.⁵⁰ In 2014, Zamboni *et al.* noticed increase cuspal deflection in the CAD/CAM technique.⁵¹

Composites CAD/CAM restorations immersed in staining solutions showed less color stability in comparison to conventional laboratory-processed resin composites.⁵² The shade match of CAD/CAM porcelain veneers was not affected by the translucency of used milling block or the opacity of the resin cement.⁵³

Bosch *et al.* (2014) investigated the influence of various milling processes on the accuracy of ceramic restorations. They stated that restorations milled with a 5-axial milling unit have a higher exactness than those milled with a 4-axial milling unit. A rotary cutting instrument with a smaller diameter led in a more exactitude milling process. The 2-step mode is not significantly better than the 1-step mode.⁵⁴

Lithium disilicate crowns performance was characterized significant after 2 years of clinical service.³⁸ Reich *et al.* (2010) assessed the clinical performance of chair-side -generated crowns during a preliminary time-period of 2 years. They declared that the crowns showed clinically satisfying outcomes.⁵⁵

After a mean observation time of 46 months, Reich *et al.* (2014) recorded the failure-free rate, and complication-free rate were revealed as 93 and 83%, respectively.⁵⁶ The clinical performance of the crowns was exactly satisfying.⁵⁷

Roggendorf *et al.* (2012) reported a total of 96.4% of the restorations revealed sufficient ratings for esthetic properties "anatomic form," "color match," "marginal discoloration," and "marginal integrity." The survival rate of 86.9% at the 7 years recall indicated that adhesively luted all-ceramic CAD/CAM-generated restorations are suitable for restoration of extended coronal distortion.⁶

Long-term survival rates for CAD/CAM restorations appear to be similar to the traditional one.⁵⁸ The survival rate was 88.7%

after up to 17 years of clinical service for CEREC CAD/CAM restorations considered very respectable clinical result. A total of (11%) failure was found (62%) to ceramic fractures (14%) tooth fractures (19%) caries and (5%) endodontic problems.⁵⁹

Wiedhahn *et al.* (2005) studied the long-term treatment outcome of CAD/CAM generated porcelain laminate veneers. After 9 years, they reported 94% survival rate.⁶⁰ In another study after a mean monitoring period of 4 years, the failure-free rate was 96.3% one failure presented crown fracture after 2.8 years. Two abutments changed the sensibility from positive to negative within the first 13 months. Two abutment teeth revealed secondary caries below the crown margin.⁵⁷

Attia *et al.* (2006) found that the cyclic loading fatigue significantly decrease the fracture loads of composite resin and all-ceramic crowns while adhesive cementation significantly expanded the fracture loads.⁶¹

CAD/CAM inlays had less cement thickness than laboratory-made inlays, but this was not related to their microleakage.⁶² A thinner film of cementation is recommended for Chair-side CAD/CAM ceramic restorations.⁶³ In 2012, Kassem *et al.*, found that composite crowns were more fatigue-resistant than ceramic crowns. Cement type had a significant effect on fatigue resistance of the ceramic crowns but not the composite ones. Microleakage scores of ceramic crowns cemented with PAN (Panavia-F-2.0) were significantly lower.⁶⁴ Fasbinder *et al.* (2010) pointed out that there was no concrete change in the crowns during the 2 years study also there was no reported sensitivity at 1 or 2 years or crown fracture or surface chipping. For margin discoloration, the percentage Alfa score was 86.9% for crowns cemented with self-etching, dual-curing cement. All other percentage Alfa scores were greater than 92.0%.³⁸

Conclusion

The application of CAD/CAM technology is promising for the delivery of high-quality devices in all fields of dentistry. It is esthetically pleasing, effective; time-saving and can be applied successfully in private practice. The way of producing and placing the restorations made with the chair-side CAD/CAM (CEREC and E4D) devices is better than restorations made by conventional laboratory procedures.

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