Overview of CEREC CAD/CAM chairside system

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This article describes CAD/CAM technology used in dentistry and different restorative materials used in conjunction with adhesive cementation with particular attention given to the evolution of the CEREC system, as well as various ceramics developed for this system. Advantages and limitations of materials and technique are also discussed.

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The demand for esthetic restorations has increased dramatically over the past two decades. The search for new methods has been driven in part by patients who have increasingly high expectations in esthetic dentistry and concerns about the introral biocompatibility of metals.1 While metal-ceramic systems are a high-strength mode of treatment with positive long-term success rates, they also are associated with certain disadvantages, including esthetic concerns and potential for allergic reactions (gold allergies are rare, but have been documented in the literature).2 Several studies have investigated the prevalence of metal contact allergy among various populations.3-7 Metal contact allergy was reported to be 0.8%-9.5% for gold, 1.6% for silver, 9% for cobalt, 8.2% for tin, 8% for palladium, 8% for chromium, and 14.3%-29% for nickel.3-7

Ceramics have become a popular restorative material due to their high esthetic quality, wear resistance, durability, color stability, and biocompatibility.8-12 Disadvantages of ceramics include the high cost of fabrication, low fracture resistance, difficulty in repairing, excessive wear of opposing teeth, the need for a more aggressive preparation design, technique sensitivity, and less-than-ideal marginal adaptation.8-12

Advancements in dental materials, computer technology, and equipment have made it possible to fabricate an indirect esthetic restoration in one appointment while the patient is waiting. The computer-aided design/computer-aided manufacture (CAD/CAM) CEREC (computer-assisted CERamic REConstruction) system is used for electronically designing and milling restorations. Using this system, the dentist can manufacture a restoration without the need for laboratory assistance, impressions, or temporary restorations.17 The restoration can be designed in less than five minutes and milled in 10-12 minutes, resulting in significant time savings for both the patient and dental practice.18 The CEREC system (Sirona Dental Systems, Inc.) was the first operational CAD/CAM system to be used in the dental offices.19 The first chairside inlay was fabricated with the CEREC I in 1985.20 In 1988, onlay and veneer capabilities were added to the unit. Full and partial crowns and copings were made possible in 1994 with the introduction of the CEREC 2. In 2000, the CEREC 3 (Sirona Dental Systems, Inc.) was introduced; by 2003, the CEREC units had 3-dimensional capability. New software was added in 2005 that enabled automatic virtual occlusal adjustment.20

Several studies criticized the marginal fit of CEREC restorations.21,22 However, with the latest improvements in the CEREC unit and software, it is possible to produce a more clinically acceptable marginal fit of the milled restorations.23-24

The design and manufacturing process involves optically scanning and digitizing dies created from the master impression of the prepared teeth/cores, so that the dimensions of the margins may be duplicated precisely. The scanned 3-dimensional images of the dies are then used to design the substructure, prompted by computer software. The CAD unit is linked to a robotic CAM center that creates a restoration according to the design specifications.1

Advantages of the CEREC technology

The clinical success and longevity of CEREC restorations have been documented in the literature.25 Restoration size, tooth vitality, and tooth location do not significantly affect the prognosis. A 2003 study by Posselt & Kerschbaum reported a survival probability of 95.5% over nine years.25 The CAD/CAM ceramic blocks are fabricated under optimum conditions, creating a restoration with higher intrinsic strength without the variation in materials found in laboratory-fabricated restorations.26 The computer-controlled fabrication diminishes the potential for inaccuracies due to human error and makes it possible to generate a restoration within a clinically acceptable fit of 50 µm, as established by the American Dental Association.27

Because only one appointment is needed to complete the restoration, the patient is subjected to only one administration of local anesthetic. In addition, there is no need to fabricate a temporary restoration which is at risk of loss, breakage, or leakage and may produce sensitivity and/or contaminate the dentinal tubules.28 Temporary restorations may be hard to clean and maintain during the temporization period, which can lead to gingival irritation; in addition, pulpal stress may occur when the temporary restoration is removed, due to excessive cleaning, drying, or trauma.29

By manufacturing and completing the restoration in a single appointment, the office can improve efficiency by decreasing second-chair setup costs, reducing the number of instruments that require sterilization, and eliminating the cost of disposable supplies required for conventional restorations (including impression materials, wax, stone, temporary resin material, and temporary cement).29 In addition, the clinician has complete control over the final result and esthetics of the restoration since the software delivers a restoration that should require only staining or glazing.29 A well-trained, dedicated staff is mandatory for a successful restoration. However, staff...
members can make the restoration after the dentist has prepared the tooth. This saves time, which adds to the financial viability of the CEREC technology.

CEREC restorations are associated with minimal reported postoperative sensitivity, due to rubber dam isolation in the clinical trials that ensures a clean, isolated tooth surface for adhesion bonding.  

Inserting the restoration at the same appointment as the preparation prevents possible tooth contamination during the temporization phase; in addition, using factory-manufactured composite and ceramic blocks minimizes the polymerization shrinkage by limiting it to the resin-cement interface. Finally, no laboratory fee is involved with CAD/CAM restorations.

**Limitations of CEREC technology**

One factor that could limit the use of CEREC technology is the cost of the equipment, especially for dentists in solo practices. In addition, the color of the finished restoration may not be ideal since the restoration is milled from a monochromatic block. However, multicolor blocks have been developed to overcome this limitation; in addition, dentists can place superficial stains to mimic any shade variability in the patient’s teeth.

It takes significant time for a dentist to become proficient enough in the use of this system to achieve financial success. A 2007 study reported that dental students introduced to CEREC 3 in their last semester were able to produce clinically acceptable inlays with a high short-term (2 years) success rate.

It is difficult to digitally capture subgingival-placed margins for severely broken teeth; in such cases, gingival retraction is needed.

CAD/CAM technology in the dental office is limited to single units only, and a CEREC restoration takes longer to polish compared with a laboratory-manufactured restoration. However, with experience, the dentist may become faster and more efficient in performing these tasks.

**Concerns of the CEREC materials**

**Strength**

The blocks used with the CEREC equipment are fabricated under ideal manufacturing conditions in a reproducible manner that eliminates human error, which results in a dense, defect-free, high-quality material. Conventionally fabricated restorations are made by hand, which may lead to human error that could affect the restoration’s mechanical and esthetic properties. A 2000 study by Tinschert et al concluded that industrially prepared ceramics are more structurally reliable than conventional laboratory-fabricated ceramics, although CAD/CAM milling procedures may induce surface and subsurface flaws that may adversely affect the strength of this ceramic. However, the strength can be restored by polishing the material with rubber wheels and diamond paste. Further enhancement of strength (to approximately 160 MPa) can be acquired by a combination of polishing and glazing.

In a 2004 study, Attia and Kern concluded that the fracture resistance of teeth restored with CEREC-manufactured crowns was equal to that of unprepared natural teeth, but was significantly higher than that in teeth restored with conventional low-fusing ceramic crowns.

**Esthetics**

As noted earlier, the esthetics of CEREC materials are a concern due to the monochromatic nature of the blocks. However, a porcelain restoration can be stained and glazed after milling; in addition, the blocks are available in a variety of shades to match the adjacent natural dentition. A clinical study by Herguth et al compared the esthetics of CEREC-manufactured crowns to crowns fabricated using the layering technique, and concluded that both restorations were esthetically acceptable to all patients with no statistically significant difference in the esthetic ratings between the two crowns.

A series of studies evaluated 66 ceramic inlays (Vitablocs Mark II, Vident) and reported that the color mismatch increased after 10 years from 16% to 38%. According to Fasbinder et al, the increased color mismatch was due to the tooth changing color rather than a color shift in the milled restoration. More recently, Fasbinder et al reported a significantly better color match for CEREC-manufactured composite inlays (Paradigm, 3M ESPE) compared with Vitablocs Mark II ceramic inlays at 3 years, as the composite resin appeared to reflect the surrounding tooth color to a better degree than the ceramic inlays.

CEREC-manufactured restorations can provide an esthetically acceptable restoration when polished, and an esthetically optimum one when stained and glazed. The decreased color match over time can be attributed to a change in tooth shade and translucency, rather than a change in the color of the CEREC-manufactured restoration.

**Postoperative sensitivity**

Early clinical studies reported significant levels of postoperative sensitivity among CEREC restorations. In a study of 301 inlays, Magnuson et al reported that 9% experienced immediate post-operative sensitivity. Most cases involving post-operative sensitivity resolved within 1 month. A 3-year clinical study by Fasbinder et al reported that 13% of 92 Vitablocs Mark II onlays were slightly sensitive after 1 week, and 4% of the 92 onlays were slightly sensitive after 2 weeks. All postoperative sensitivity was resolved after 1 month, and no other postoperative sensitivity was reported during the 3-year period of observation. Most cases of postoperative sensitivity can be attributed to occlusal interference, since the restorations are inserted in a single appointment. Fasbinder advised equilibrating the occlusal contacts after the effects of the local anesthetic have dissipated.

More recent studies have reported less postoperative sensitivity, which could be attributed to the significant improvement of the adhesive materials. Molin & Karlsson examined 20 CEREC-generated Vitablocs Mark I inlays (Vident) over five years and reported no postoperative sensitivity throughout the observation period.

The absence of significant postoperative sensitivity in such restorations can be attributed to several factors. First, the optical imaging of the preparation requires careful isolation, which ensures optimum fluid control and which maximizes the predictability of cementation. The fact that CEREC-manufactured restorations eliminate the need for temporization contributes to the lack of postoperative sensitivity, preventing contamination of the dentin tubules during the temporization period that can occur with a lost, fractured, or leaking temporary restoration.
Margin adaptation
In 2003, Nakamura et al studied how abutment occlusal conversion angle and the computer luting space setting affected the internal fit and marginal adaptation of the ceramic CEREC 3-milled restoration. The authors found that setting the computer luting space at 30-50 µm produced a marginal gap of 53-67 µm that was not influenced by the abutment angle of occlusal conversion. Other researchers measured gaps of approximately 50 µm, suggesting that the marginal fit of CAD/CAM-generated restorations is adequate for clinical use. Denissen et al reported a margin gap of 85 µm for CEREC 3-manufactured onlays, a gap that was not significantly different from laboratory-fabricated onlays. These recorded gaps are well within the reported maximum clinically accepted gap of 120 µm.

A well-fitting margin is expected to maximize the longevity of a restoration. Almost all clinical studies of CEREC-manufactured restorations reported ditching due to wear of the composite resin cement at the margin. However, this ditching was not associated with margin discoloration or recurrent decay. A 1992 clinical study of CEREC-manufactured inlays cemented with microfilled or hybrid resin-based composite luting agent reported a linear wear rate in the first year that decreased after 3 years by approximately 50%. The authors reported that the vertical loss of cement at the margin stopped when it reached 50% of the margin width and that no microleakage or secondary decay was reported at the margin. More recently, Heymann et al reported that the wear of the adhesive luting agent at the occlusal margin of inlays increased over the first 3 years, and decreased over the next 3 years. No margin chipping or staining was identified in the enamel or porcelain inlays as the adhesive cement started to wear. In an in vitro comparative study with hot-press technique and CEREC-manufactured restorations, Keshvad et al reported that leucite-reinforced glass-ceramic inlay restorations fabricated using CAD/CAM technology and the hot-pressed technique provided clinically acceptable marginal and internal fit with comparable fracture loads after luting.

Enamel wear
Enamel wear is always a concern when ceramics are used as a restorative material. Several factors may influence how ceramics affect enamel tooth structure. It is possible to minimize enamel wear by using fine-grained ceramics and polishing or glazing the ceramic surface. Several studies have demonstrated that the wear of enamel against polished or glazed ceramic restorations was essentially the same as that for enamel against enamel.

Longevity
Several studies have examined the success and longevity of CEREC-manufactured restorations. In the first such clinical trial, Mormann et al evaluated 94 Vitablocs Mark I inlays between September 1985 and August 1987 and reported only 2 fractured inlays during that time. In 2002, Otto & De Nisco studied 200 Vitabloc Mark II inlays over 10 years of clinical service and reported a 90.4% survival rate. In 8 cases, failure was caused by ceramic fracture; in 3 cases, by tooth fracture. In a 2004 in vivo study, Bindl & Mormann compared 18 anterior Vitablocs Mark II crowns to 18 anterior ceramic core crowns over 2 to 5 years. The ceramic core crown survival rate was 91.7%, compared to 94.4% for Vitablocs Mark II, without a statistically significant difference.

A 2003 study by Posselt & Kerschbaum evaluated 2,328 ceramic inlays and onlays in 794 patients and reported a survival rate of 95.5% at 9 years. The majority of failures were caused by inlay fracture, tooth fracture, tooth extraction, and replacement for occlusal reconstruction. A series of articles evaluated 1,011 inlays and onlays placed in 299 patients between 1987 and 1990 for up to 18 years. The authors determined a survival probability of 95% after 5 years, 91.6% after 7 years, and 90.0% at 10 years; a survival rate comparable to conventional ceramic restorations.

The low failure rate of CEREC-manufactured restorations documents the reliability and the clinical predictability of such restorations.

Ceramics used for chairside CEREC
Feldspathic porcelain-based ceramic
Vitablocs Mark II is a fine-grained feldspathic ceramic that produces fine crystal (average size = 4 µm). The pore-free ceramic is easier to polish and demonstrates low enamel wear and high strength. According to the manufacturer, the feldspar particles are uniformly embedded in the glass matrix, avoiding a detrimental “sand- ing (abrating) effect” on the antagonist. When polished, the strength of this ceramic material is approximately 130 MPa and it could reach 160 MPa or higher if glazed. This strength is approximately twice that of conventional feldspathic ceramics and also is higher than several pressable ceramics.

Empress CAD blocks
IPS Empress CAD (Ivoclar Vivadent) is a leucite glass-ceramic of the SiO₂-Al₂O₃-K₂O materials system with leucite crystals ranging from 5 to 10 µm in size. The leucite (KAlSiO₃) crystals increase the material’s strength and slow down or deflect crack propagation, while the crystalline phase absorbs fracture energy. According to Giordano, this leucite-reinforced ceramic material has properties of strength and surface characterization similar to those found in Vitablocs Mark II.

IPS e.max CAD blocks
IPS e.max CAD (Ivoclar Vivadent) is a lithium disilicate glass-ceramic for CAD/CAM applications. The blocks are produced by massive casting of transparent glass ingots. A continuous manufacturing process based on glass technology (that is, pressure-casting) is utilized to prevent the formation of defects (pores, accumulation of pigments, and so forth) in the bulk of the ingot. Partial crystallization ensures that the blocks can be processed in a crystalline intermediate phase, which enables fast machining with CAD/CAM systems. The partial crystallization process leads to a formation of lithium metasilicate (Li₂SiO₃) crystals, which are responsible for the material’s optimal processing properties, edge stability, and relatively high strength.

After the milling procedure, the restorations are tempered and lithium disilicate (Li₂SiO₃) crystals are formed, which impart the ceramic object with the desired high strength. A 2010 study by Guess et al tested monolithic CAD/CAM lithium disilicate and hand-layer-veneered zirconia all-ceramic crowns and found that using IPS e.max CAD

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resulted in fatigue-resistant crowns, while hand-layer-veneered zirconia crowns revealed early veneer failures.64

Paradigm MZ100
Paradigm MZ100 (3M ESPE) is a bispheno-

A-diglycyldimethacrylate/triethylene glycol dimethacrylate resin-based compos-
ite with filler composed of nanocrystalline zirconia in an amorphous silica matrix.65 Paradigm MZ100 block material contains 85% ultrafine zirconia-silica ceramic par-
ticles by weight, which reinforce a highly crosslinked polymeric matrix (with a mean particle size of 0.6 µm). It has superior physical properties compared to conven-
tional resin due to controlled manufactur-
ing conditions, which leads to a dense and pore-free material that is completely dry cured throughout. An in vitro study by Kassem et al found that crowns made with Paradigm MZ100 were highly resistant to failure from mechanical fatigue and produced significantly higher mean microleak-
age scores compared to ceramic crowns.66 More recently, the same authors conducted an in vitro study in which Paradigm MZ100 and fine particle feldspar ceramic blocks crowns were submitted to ther-
cycling (500 cycles) and load-cycling (1,000,000 cycles ranging from 60-600 N). The results indicated that Paradigm MZ-100 crowns were more resistant to fracture after combined load and thermal load; in addition, microleakage scores were similar for both types of crowns.67

Summary
In this review, the authors presented current evidence suggesting that CEREC-manufactured restorations have an acceptable marginal adaptation and clinical longevity along with reduced chair time and improved esthetics. Evidence from many clinical studies suggests that clinicians may choose this system on the basis of patients’ esthetic needs. The evidence pro-
vided here should enable clinicians to enter into informed consent decisions with their patients who desire all-ceramic restorations.

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Disclaimer
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