# Material Matters: A Review of Chairside CAD/CAM Restorative Materials

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## Abstract

The continued evolution of chairside computer-assisted design/computer-assisted manufacture (CAD/CAM) technology for delivering single-appointment restorations has had a significant impact on the array of materials available for in-office fabrication of dental restorations. For ease in understanding their properties and clinical applications, these restorative materials may be categorized based on material composition. Chairside CAD/CAM represents the fabrication process, but the clinical outcome of the restoration is influenced more by the restorative material and how it is handled. This article presents a review of currently available materials for chairside CAD/CAM systems in an effort to help clinicians make the most informed decision on restoration options for predictable success.

**Key Words: CAD/CAM, chairside restorations, materials, ceramics, composite, zirconia**

> With more and more dentists utilizing CAD/CAM technology and manufacturers continually expanding their offerings of materials, an informed understanding of the myriad CAD/CAM restorative materials will aid a clinician's selection process.

## Introduction

The technology and the quality of materials used are critical in achieving esthetically superior restorations. With more and more dentists utilizing CAM/CAD technology and manufacturers continually expanding their offerings of materials, an informed understanding of the myriad CAD/CAM restorative materials will aid a clinician's selection process.

CAD/CAM technology is a digital workflow to fabricate restorations. This process requires three general sequences:

1. Recording the intraoral condition to a computer software program using an intraoral scanner or camera.
2. Manipulating the digital data in the design sequence using a software program to create the desired contours, occlusion, and contacts of the restoration.
3. Fabricating the designed restoration using a subtractive manufacturing process to shape or mill the desired restoration contour from a preformed block of material based on the volumetric design created with the software program.

Digital technology for dental treatment generally refers to equipment and software required for restoration fabrication. It is incumbent on the clinician to determine what specific equipment is optimal for leveraging the CAD/CAM process in the dental office. Digital impression systems focus on intraoral imaging, limited to the first sequence of CAD/CAM technology. The recorded data file is transmitted to a dental laboratory for design and processing of the restoration. Alternatively, using a chairside system, the entire CAD/CAM workflow can be leveraged for chairside fabrication of the restoration.

Restorations typically are referred to by their system name (e.g., a PlanScan restoration, a Carestream restoration, a CEREC restoration). However, these terms actually denote the digital design and fabrication process, not the composition of the restorative material. Features unique to all CAD/CAM materials are that they are monolithic and industrially processed. This results in a dense, single homogeneous material throughout the restoration rather than a bilayer restoration consisting of a coping and veneer layer.

CAD/CAM materials for chairside processing in a single appointment may be categorized based on material composition for ease in understanding their properties and clinical applications **(Table 1)**.[1,2] Each of the categories offers unique physical properties and indications for specific clinical applications. The chairside CAD/CAM system represents the fabrication process, but the clinical outcome of the restoration is more likely influenced by the category of restorative material and how it is handled.

**Table 1. Chairside CAD/CAM Restorative Materials**

| Material Category | Description | Brand | Manufacturer |
|---|---|---|---|
| Adhesive Ceramic | feldspathic glass | Vitablocs Mark II<br>CEREC Blocs | Vita Zahnfabrik<br>Dentsply Sirona |
| | leucite-reinforced glass | IPS Empress CAD | Ivoclar Vivadent |
| High-Strength Ceramic | lithium disilicate | IPS e.max CAD | Ivoclar Vivadent |
| | zirconia-reinforced lithium silicate (precrystallized) | Celtra Duo | Dentsply Sirona |
| Resilient Ceramic | nanoceramic | Lava Ultimate<br>Cerasmart | 3M<br>GC America |
| | hybrid ceramic (PICN) | Enamic | Vita Zahnfabrik |
| Composite Resin | Bis-GMA composite | Paradigm MZ100<br>Brilliant Crios | 3M<br>Coltene/Whaledent |
| Zirconia | presintered zirconia | CEREC Zirconia<br>e.max ZirCAD<br>Katana Zirconia | Dentsply Sirona<br>Ivoclar Vivadent<br>Kuraray Noritake Dental |

## Materials

### Adhesive Ceramics

The introduction in the 1980s of the first CAD/CAM systems ushered in a dramatic change in the fabrication of chairside restorations. Adhesive ceramic materials were the first millable materials developed for CAD/CAM systems. This category includes materials with a significant glass component, resulting in higher translucency; this provides a "chameleon" effect that allows the material to blend well with the existing tooth shade. Exhibiting a moderate flexural strength of 125 to 175 megapascals (MPa), these materials are not independently strong enough to be delivered with traditional cements. However, the glass component of the material can be etched with hydrofluoric acid to create micromechanical retention for adhesive bonding. Adhesive bonding not only provides dependable retention, but it also seals the internal aspect of the restoration against cracks and improves resistance to functional fracture.[3]

**Feldspathic and leucite-reinforced materials:** Two types of materials are marketed in this category. One group is composed of fine-grained feldspathic porcelain (Vitablocs Mark II, Vita Zahnfabrik; Bad Sackingen, Germany, and CEREC Blocs, Dentsply Sirona; York, PA) **(Figs 1-3)**; the other group is composed of leucite-reinforced ceramic (IPS Empress CAD, Ivoclar Vivadent; Schaan, Liechtenstein) **(Figs 4-6)**.[2,4] These materials are available as monochromatic blocks in a variety of classic shades, as well as polychromatic blocks with a progression of chroma and translucency that simulates the shade transition from cervical to incisal in natural dentition.

Most laboratory studies typically evaluate only one or two specific material properties, making it difficult to compare overall properties across studies. One in vitro study measured a variety of physical properties of adhesive ceramic materials.[4] Feldspathic glass material was significantly harder than leucite-reinforced material, which may make the feldspathic material more resistant to surface scratches and wear. Leucite-reinforced material had a greater flexural strength and fracture toughness, which may make it more resistant to fracture.[4] Physical property differences described within this material category have not been found to influence clinical longevity between the two types of adhesive ceramic materials.

Adhesive ceramic materials may be either hand-polished or glaze-fired with custom characterization to influence their esthetic outcome. Hand polishing creates an optimally smooth surface for functional wear with antagonist teeth. This category of materials is indicated for single-tooth restorations (e.g., inlays, onlays, veneers, and crowns).

**Clinical studies:** One of the first clinical studies on chairside CAD/CAM inlays was published in 1991.[5] A CEREC 1 unit (Dentsply Sirona) was used to deliver 35 premolar and 59 molar feldspathic porcelain inlays (Vitablocs Mark I) between September 1985 and August 1987. Two fractured inlays were reported after three years of clinical service. This early study was one of the first to indicate that milled ceramic restorations had the potential for desired clinical outcomes and longevity in a chairside application.

**Figures 1-3:** Feldspathic ceramic onlay (Vitablocs Mark II) #19 at one-month, three years, and five years.

**Figures 4-6:** Leucite-reinforced ceramic onlay (Empress CAD) #3 at the time of delivery, two years, and five years.

As adhesive ceramic materials have been available for more than 25 years, numerous long-term clinical studies have been published. A series of articles on 1,011 chairside CAD/CAM restorations placed with the CEREC system between June 1987 and September 1990 was published from 1991 to 2006. The restorations, performed on 299 patients in a private practice, were recalled for up to 18 years. After five years, the survival probability was 95%; after seven years, the Kaplan-Meier curve dropped to 91.6%.[6,7] The survival probability was 90% at 10 years and declined to 84.9% at 16.7 years.[8] No significant difference in survivability based on the number of tooth surfaces restored was reported.

The clinical research published on chairside CAD/CAM restorations prior to 2004 was based on adhesive ceramic materials, as they were the only category of chairside CAD/CAM material available. A comprehensive review of clinical studies published prior to 2005 was published in 2006 and provides additional detailed information on these studies.[9]

### High-Strength Ceramics

**Lithium disilicates and zirconia-reinforced lithium silicates:** The introduction of ceramic materials with improved strength properties marked an important development in CAD/CAM materials. IPS e.max CAD was introduced in 2006 as a lithium disilicate material with a significantly greater flexural strength and fracture toughness than previous adhesive glass ceramics.[10,11] The block consists of 0.2-1.0 micron (μm) lithium meta-silicate crystals 40% by volume. The manufactured block is a blue-violet color, which accounts for the commonly used "blue block" description. This partially crystallized "soft" state (i.e., ~140 MPa) allows the block to be milled easily without excessive diamond bur wear or damage to the material. Post milling, the restoration must be subjected to a two-stage firing cycle in a ceramic furnace at 850° C under vacuum to complete the crystallization process. During crystallization, the meta-silicate

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**Figures 7 & 8:** Glazed zirconia-reinforced lithium silicate crown (Celtra Duo) #19 at the time of delivery and at one year.

crystals are dissolved, the lithium disilicate crystallizes, and the ceramic is simultaneously glazed. The restoration changes from the blue color to the chosen shade and achieves the material's maximum flexural strength potential (i.e., 500 MPa). The crystallization firing produces a glass ceramic restoration with a grain size of approximately 1.5 µm with a 70% crystal volume incorporated in a glass matrix, as well as creates the optimum translucency for the material.[12]

Another example of a high strength CAD/CAM ceramic, Celtra Duo (Dentsply Sirona) was introduced in 2012 as a zirconia-reinforced lithium silicate (ZLS). The ZLS microstructure has a high content of ultra-fine glass ceramic crystals (i.e., <1.0 µm). Zirconium dioxide (10%) is unique to the composition of Celtra Duo and is completely diluted in amorphous glass. It creates a fine-grained structure that increases the material strength, yet allows the material to be readily machined. The manufacturer provides Celtra Duo in a fully crystallized state that may be either hand-polished or glaze-fired in a ceramic furnace prior to delivery. Hand polishing the restoration results in a material that has a flexural strength of 210 MPa, while glazing it in a porcelain oven results in a restoration with a flexural strength of 370 MPa **(Figs 7 & 8)**.[13] Both IPS e.max CAD and Celtra Duo are also available to dental laboratories as press-fit ingots.

The category of high-strength ceramic materials has become the most popular for chairside restorations. Clinicians appreciate the combination of the materials' improved strength and good translucency with their ease of use in surface finishing to fabricate natural-looking restorations. Maximum strength is dependent on oven glazing for ZLS restorations and oven crystallization for lithium disilicate restorations. Clinicians apparently find these additional in-office processing steps acceptable, since they result in restorations with higher strength properties. This category of materials is indicated for single-tooth restorations (e.g., inlays, onlays, veneers, and crowns). Lithium disilicate also is available in specifically designed blocks for short-span fixed partial dentures and the restoration of dental implants.

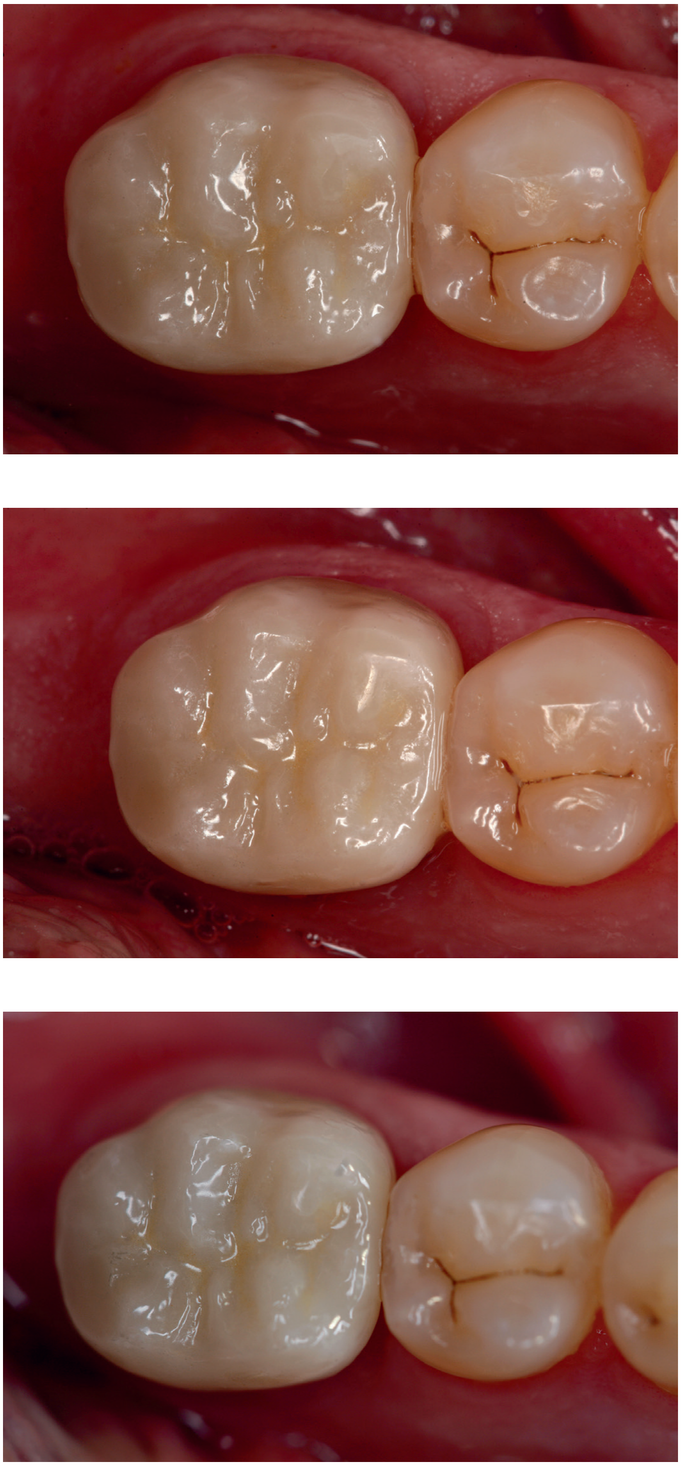
**Clinical studies:** The introduction of high-strength CAD/CAM materials offered an opportunity to evaluate the degree to which higher strength influenced clinical outcomes. One clinical study evaluated the performance of chairside CAD/CAM lithium disilicate (IPS e.max CAD) crowns fabricated with the CEREC system during a single appointment.[14] Forty-one full crowns were cemented with a dual-cure, self-adhesive resin cement (Multilink Sprint, Ivoclar Vivadent). At the two-year recall, 39 crowns were available for examination. Kaplan-Meier analysis resulted in a two-year survival rate of 97.4%. The failures observed were not due to material fracture; one crown exhibited secondary caries and two crowns received root canal treatment. A four-year follow-up was conducted and a success rate of 96.3% was reported.[15]

A retrospective study of lithium disilicate restorations included the clinical performance of 21 monolithic lithium disilicate (IPS e.max CAD) posterior crowns fabricated chairside with the CEREC system. All crowns were adhesively cemented using either a self-adhesive (RelyX Unicem, 3M; St. Paul, MN) or a dual-cure resin cement (Multilink Automix, Variolink II [Ivoclar]). The crowns were recalled for up to six years of clinical service. Minor cohesive fractures (i.e., chipping) occurred on three of the monolithic crowns. Posterior monolithic crowns showed cumulative survival and success rates of 96.2%.[16]

Another longitudinal clinical study evaluated the performance of 100 lithium disilicate (IPS e.max CAD) crowns at two, four, and five years.[17-19] All crowns were fabricated chairside with a CEREC unit and delivered during a single appointment **(Figs 9-11)**. The first 62 crowns were placed with either a self-etching bonding agent and adhesive resin cement or a self-adhesive resin cement. The last group consisted of 38 crowns that were delivered using experimental self-etching, self-curing cement. No crown failures were reported during the first two years, resulting in a 100% survival rate. At five years, a total of five failures were recorded—one crown fractured and four crowns debonded (three of which had been delivered with the experimental cement). All of the debonded crowns were recemented with a dual-cure resin cement and remained functional without problems through the five-year recall. This accounted for a 99% clinical survival rate at five years.

A short-term clinical study reported on glazed ZLS (Celtra Duo) restorations placed with the CEREC system.[20] A total of 78 partial premolar and molar crowns were delivered with a total etch adhesive cementation technique. All restorations were intact without fractures and asymptomatic at the two-year recall. One restoration required endodontic treatment. The Kaplan-Meier success rate was 98.8%.

Another short-term clinical study evaluated ZLS (Celtra Duo) inlays after one year of clinical service.[21] There were 27 inlays and 33 onlays fabricated with the CEREC system and adhesively delivered in a single appointment. The 60 restorations were divided between hand polishing and oven glazing to create the final surface finish. One polished molar onlay and one oven glazed molar onlay failed due to bulk fracture. The authors reported a 96.7% success rate after one year.



Figures 9-11: Lithium disilicate crown (e.max CAD) #19 at the time of delivery, two years, and five years.

### Resilient Ceramics

This newer category of chairside CAD/CAM materials is designed to take advantage of the lower brittleness and greater fracture resistance properties of polymers, while combining the esthetic characteristics of glass ceramics. Resilient ceramic materials—also referred to as resin nanoceramics, hybrid ceramics, or polymer-infiltrated-ceramic network (PICN) materials in an attempt to specifically distinguish within the category—all contain a resin matrix structure and a lower modulus of elasticity. Materials with a lower modulus of elasticity may be considered more resilient and able to resist a higher functional load without brittle fracture. Since these materials are less dense than ceramics, they mill efficiently with less margin chipping.[22]

**Nanoceramics:** Lava Ultimate (3M) is a nanoceramic CAD/CAM material that contains silica particles of 20 nanometers (nm), zirconia particles of 4 to 11 nm, and agglomerated nanosized particles of silica and zirconia, all embedded in a highly cross-linked polymer matrix with an approximately 80% ceramic load. According to the manufacturer, an advantage for the nanoceramic material over CAD/CAM composite blocks is the former's ability to retain a high-gloss surface finish over time.[2] The manufacturer reports a flexural strength of 200 MPa for Lava Ultimate, which is greater than the flexural strength of the feldspathic and leucite-reinforced porcelain blocks, and of veneering porcelains for porcelain-fused-to-metal (PFM) crowns (i.e., < 100 MPa).[2] The manufacturer indicates it for veneers, inlays, and onlays, but not for crowns. Independent laboratory studies have reported flexural strength of 170 MPa for Lava Ultimate.[22,23]

Its manufacturer describes Cerasmart (GC America; Alsip, IL) as a flexible nanoceramic with a resin matrix containing homogeneously distributed nanoceramic filler particles. The material, which is radiopaque, is a high-density composite resin with 71% silica and barium glass nanoparticles filler by weight.[22] The reported flexural strength of Cerasmart is 230 MPa and it is indicated for single-tooth restorations (e.g., veneers, inlays, onlays, and crowns).[22]

**PICN hybrids:** Introduced in 2013, Enamic (Vita) is described as a PICN. It is a resin-based (14% by weight) hybrid ceramic comprising an interpenetrating structure of a leucite-based and zirconia-reinforced ceramic network (86% by weight).[22] The material's mechanical properties are intermediate to those of adhesive ceramics and highly filled composites.[24] The ceramic network may improve wear resistance; however, it may make the material more brittle and susceptible to fracture. The polymer network can improve the material's fracture resistance due to its capability of undergoing plastic deformation.[25] This material is indicated for inlays, onlays, and crowns, and the manufacturer reports a flexural strength of 150 MPa. The latter is consistent with the results of an independent study, which reported the flexural strength to be approximately 135 ± 25 MPa.[22] A more recent introduction, Enamic IS is based on identical chemistry, but comes in a block design specific for milling implant restorations.

Resilient CAD/CAM materials offer a very good combination of fast and accurate milling with efficient finishing and polishing to minimize processing time for chairside restorations. While hand polishing quickly results in surface smoothness comparable to ceramics, shade modification is limited to the use of visible light-cured (VLC) surface tints and glazes. This category of materials does not exhibit the inherent strength to be cemented and must be adhesively bonded to the tooth structure.

**Clinical studies:** Limited clinical studies on resilient ceramic materials have been reported due to their relatively recent introduction. One randomized clinical study evaluated onlays fabricated with Lava Ultimate and IPS Empress CAD materials.[26] A total of 86 patients received 120 CEREC chairside CAD/CAM onlays equally divided between the two materials. All onlays were adhesively cemented with either a self-etch process and dual-cure resin cement (RelyX Ultimate) or a total-etch process and dual-cure resin cement (Variolink II). At the end of three years, there were five failed onlays **(Figs 12-14)**. Two of the Lava Ultimate onlays required endodontic treatment; three other onlays (i.e., two IPS Empress CAD onlays and one Lava Ultimate onlay) fractured. No significant changes in surface finish or contour were reported for either material.

A second clinical study on Lava Ultimate included 42 onlays fabricated with the CEREC system and adhesively delivered with a dual-cure resin cement (Variolink II) for 30 patients.[27] Within the first 12 months, two onlays debonded and required replacement; this resulted in a success rate of 95%. There were two fractured onlays and one additional debonded onlay that

**Figures 12-14:** Nanoceramic onlay (Lava Ultimate) #12 at the time of delivery, one year, and three years.

> The introduction of ceramic materials with improved strength properties marked an important development in CAD/CAM materials.

required replacement after two years of clinical function; this accounted for a cumulative success rate of 85.7%.

One clinical study compared Enamic onlays to Vitablocs Mark II onlays for restoration of endodontically treated teeth.[28] A CEREC system was used to deliver 101 onlay restorations (i.e., 67 Enamic and 34 Vitablocs Mark II) that were recalled for three years. Five failures were recorded—two Enamic onlays and three Vitablocs Mark II onlays. One Enamic onlay debonded at 12 months and one fractured at 12 months. Two Vitablocs Mark II onlays debonded at 24 months and one fractured at 18 months. The reported survival rates were 97% for Enamic and 90.7% for Vitablocs Mark II ($p>0.05$). There were no significant differences between the success rates of restoring extensively damaged teeth and short clinical crowns between the two groups ($p>0.05$).

Another clinical study evaluated 103 Enamic restorations (i.e., 45 inlays and 58 onlays) over three years of clinical service.[29] All restorations were fabricated chairside using a CEREC Bluecam system and adhesively delivered using a dual-cured resin cement (Variolink II) in a single appointment. Three restorations fractured requiring replacement. The reported survival rates were 97.4% for inlays and 95.6% for onlays.

## Composite Materials

Introduced in 2000, composite resin CAD/CAM materials for chairside applications have not been particularly popular. However, recent developments in the ease of use and efficiency of CAD/CAM technology have lead to an increased use of composite materials. Development of accurate occlusion, desired proximal contacts, and avoidance of postoperative sensitivity can prove problematic when using sectional matrices for the placement of large, multi-surface direct composite restorations. The chairside CAD/CAM workflow may offer a more predictable result while avoiding postoperative sensitivity using monolithic composite blocks, as there is no polymerization shrinkage to the milled restoration.

Paradigm MZ100 (3M) was the first composite block introduced. It is radiopaque, has zirconia-silica filler particles, and is 85% filled by weight with an average particle size of 0.6 µm.[30] A proprietary processing technique is used to maximize the degree of cross-linking in the Bis-GMA composite.[30] Paradigm MZ100's reported flexural strength is 157 ± 30 MPa, which is similar to the flexural strength of adhesive ceramic materials.[22]

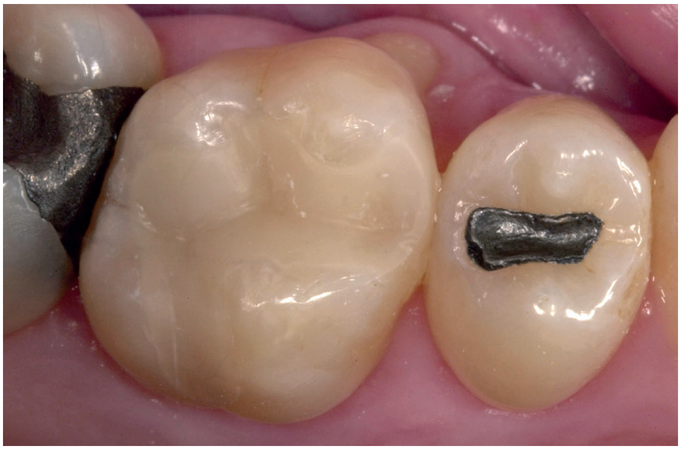
Brilliant Crios (Coltene/Whaledent; Cuyahoga Falls, OH), which was introduced in 2016, is a reinforced composite containing amorphous silica particles (< 20 nm) and barium glass ceramic particles (< 1.0 µm) in a cross-linked methacrylate matrix. The manufacturer reports a filler weight of 70.7% and filler volume of 51.5% with a flexural strength of 198 MPa and a modulus of elasticity of 10.3 GPa. The modulus of elasticity, similar to that of dentin, is suggested to minimize stress concentration in the restoration and avoid brittle fracture.

**Clinical studies:** Minimal clinical research currently exists on CAD/CAM composites, but one clinical study reported the three-year, six-year, and 10-year results of a randomized clinical trial of 40 Paradigm MZ100 inlays and 40 Vitablocs Mark II inlays.[9,31] All inlays were cemented using a total-etch bonding technique with a dual-cure resin cement (RelyX ARC) **(Figs 15-17)**. At the 10-year recall, 89% of the inlays were available for evaluation. The composite inlays exhibited no significant change in color match from baseline, while the porcelain inlays exhibited a decrease in color match at six months. This color discrepancy, attributed to changes in tooth color, remained unchanged. There was one composite inlay fracture and five porcelain inlays fractures at 10 years, with a calculated survival rate of 95% for Paradigm MZ100 inlays versus 87.5% for Vitablocs Mark II inlays. The calculated annual failure rates were 0.5% for composite inlays and 1.25% for ceramic inlays.

## Zirconia

The newest material category for chairside CAD/CAM materials is full-contour zirconia. CEREC Zirconia (Dentsply Sirona), precolored zirconia blocks for full-contour restorations, was introduced in 2016. A concomitant development and introduction of an innovative induction-sintering oven (SpeedFire, Dentsply Sirona) significantly reduced the sintering process to less than 20 minutes, thus allowing for single-appointment processing and delivery. Zirconia has a flexural strength and fracture toughness that is typically at least three times that of adhesive glass ceramic materials.[32] The reported flexural strength for CEREC Zirconia is more than 1000 MPa.[33] Zirconia's high strength allows for conventional cementation rather than adhesive bonding for retention, assuming adequate resistance and retention form exist.

As a new category of chairside CAD/CAM material, zirconia is likeliest to experience the most developments going forward. In general, zirconia materials have been evolving into formulations with greater translucency and sufficient strength to be cemented rather than adhesively bonded. Newer full-contour zirconia materials for chairside CAD/CAM application, such as Katana Zirconia (Kuraray Noritake Dental; Tokyo, Japan) and IPS e.max ZirCAD, have been introduced with improved translucency and polychromatic esthetic shading. However, to date, limited clinical evidence exists regarding these materials.



**Figures 15-17:** CAD/CAM composite onlay (Paradigm MZ100) #3 at the time of delivery, three years, and six years.

## Summary

The term *chairside CAD/CAM restoration* obviously is not particularly descriptive of the actual restoration that is fabricated, based on the diverse array of material options available. Understanding the material categories and their differing properties and handling characteristics will play an influential role in selecting a specific material for a particular clinical situation. A significant amount of clinical evidence supports the premise that attention to the unique properties and features of the various categories of CAD/CAM materials can result in excellent clinical outcomes.

### References


1. Fasbinder DJ. Materials for chairside CAD/CAM restorations. Compend Contin Educ Dent. 2010 Nov-Dec;31(9);702-4, 706, 708-9.

2. Fasbinder DJ. Chairside CAD/CAM: an overview of restorative material options. Compend Contin Educ Dent. 2012 Jan;33(1):50-8.

3. Addison O, Marquis PM, Fleming GJ. Resin strengthening of dental ceramics—the impact of surface texture and silane. J. Dent. 2007 May;35(5):416-24.

4. Charlton DG, Roberts HW, Tiba A. Measurement of select physical and mechanical properties of 3 machinable ceramic materials. Quintessence Int. 2008 Jul-Aug;39(7):573-9.

5. Mormann WH, Gotsch T, Krejci I, Lutz F, Barbakow F. Clinical status of 94 CEREC ceramic inlays after 3 years in situ. In: WH Mormann, editor. International Symposium on Computer Restorations 1991: state of the art of the CEREC-method. Chicago: Quintessence Pub.; 1991. p. 355.

6. Reiss B, Walther W. Survival analysis and clinical evaluation of CEREC restorations in a private practice. In: WH Mormann, editor. International Symposium on Computer Restorations 1991: state of the art of the CEREC-method. Chicago: Quintessence Pub.; 1991, p. 215.

7. Reiss B, Walther W. Clinical long-term results and 10-year Kaplan-Meier analysis of Cerec restorations. Int J Comput Dent. 2000 Jan;3(1):9-23.

8. Reiss B. Clinical results of Cerec inlays in a dental practice over a period of 18 years. Int J Comput Dent. 2006 Jan;9(1):11-22.

9. Fasbinder DJ, Dennison JB, Heys DR, Lampe K. Clinical evaluation of CAD/CAM-generated composite inlays: Six-year report. J Dent Res. 2006 85(Spec Issue A): Abstract 543.

10. Albakry M, Guazzato M, Swain MV. Biaxial flexural strength, elastic moduli, and x-ray diffraction characterization of three pressable all-ceramic materials. J Prosthet Dent. 2003 Apr;89(4):374-80.

11. Belli R, Geinzer E, Muschweck A, Petschelt A, Lohbauer U. Mechanical fatigue degradation of ceramics versus resin composites for dental restorations. Dent Mater. 2014 Apr;30(4):424-32.

12. Culp L, McLaren EA. Lithium disilicate: the restorative material of multiple options. Compend Contin Educ Dent. 2010 Nov-Dec;31(9):716-20, 722, 724-5.

13. Zimmermann M, Mehl A, Reich S. New CAD/CAM materials and blocks for chairside procedures. Int J Comput Dent. 2013;16(2):173-81.

14. Reich S, Fischer S, Sobotta B, Klapper HU, Gozdowski S. A preliminary study on the short-term efficacy of chairside computer-aided design/computer-aided manufacturing-generated posterior lithium disilicate crowns. Int J Prosthodont. 2010 May-Jun;23(3):214-6.

15. Reich S, Schierz O. Chair-side generated posterior lithium disilicate crowns after 4 years. Clin Oral Investig. 2013 Sep;17(7):1765-72.

16. Fabbri G, Zarone F, Dellificorelli G, Cannistraro G, De Lorenzi M, Mosca A, Sorrentino R. Clinical evaluation of 860 anterior and posterior lithium disilicate restorations: retrospective study with a mean follow-up of 3 years and a maximum observational period of 6 years. Int J Periodontics Restorative Dent. 2014 Mar-Apr;34(2):165-77.

17. Fasbinder DJ, Dennison JB, Heys D, Neiva G. A clinical evaluation of chairside lithium disilicate CAD/CAM crowns: a two-year report. J Am Dent Assoc. 2010 Jun;141 Suppl 2:10S-14S.

18. Fasbinder DJ, Dennison JB, Heys D, Neiva GF. Clinical evaluation of lithium disilicate chairside CAD/CAM crowns at 4 years. J Dent Res. 2012 91(Spec Issue A): Abstract 645.

19. Fasbinder DJ, Dennison JB, Heys D, Neiva GF. Five-year clinical evaluation of lithium disilicate chairside CAD/CAM crowns. J Dent Res. 2015 94(Special Issue A): Abstract 247.

20. Rinke S, Pfitzenreuter T, Roediger M, Ziebotz D. Clinical evaluation of chair-side-fabricated posterior partial crowns—24 month results. J Dent Res. 2017 96(Spec Issue A): Abstract 184.

21. Zimmermann M, Koller C, Mehl A, Hickel R. Indirect zirconia-reinforced lithium silicate ceramic CAD/CAM restorations: preliminary clinical results after 12 months. Quintessence Int. 2017;48(1):19-25.

22. Awada A, Nathanson D. Mechanical properties of resin-ceramic CAD/CAM restorative materials. J Prosthet Dent. 2015 Oct;114(4):587-93.

23. Albero A, Pascual A, Camps I, Grau-Benitez M. Comparative characterization of a novel CAD/CAM polymer-infiltrated-ceramic-network. J Clin Exp Dent. 2015 Oct 1;7(4): e495-e500.

24. Della Bona A, Corazza PH, Zhang Y. Characterization of a polymer-infiltrated ceramic-network material. Dent Mater. 2014 May;30(5):564-9.

25. El Zhawi H, Kaizer MR, Chughtai A, Moraes RR, Zhang Y. Polymer infiltrated ceramic network structures for resistance to fatigue fracture and wear. Dent Mater. 2016 Nov;32(11):1352-61.

26. Fasbinder DJ, Neiva GF, Dennison JB, Heys D, Heys R. Two-year clinical evaluation of CAD/CAM nano-ceramic and leucite-reinforced crowns. J Dent Res95(Spec Issue A): abstract #254, 2016.

27. Zimmermann M, Koller C, Reymus M, Mehl A, Hickel R. Clinical evaluation of indirect particle-filled composite resin CAD/CAM partial crowns after 24 months. J Prosthodont. 2017 Apr 19. doi: 10.1111/jopr.12582. [Epub ahead of print]

28. Lu T, Peng L, Xiong F, Lin XY, Zhang P, Lin ZT, Wu BL. A 3-year clinical evaluation of endodontically treated posterior teeth restored with two different materials using the CEREC AC chair-side system. J Prosthet Dent. 2017 Jul 7. pii: S0022-3913(17)30310-4. doi:10.1016/j.prosdent.2017.04.022. [Epub ahead of print]

29. Spitznagel FA, Scholz KJ, Strub JR, Vach K, Gierthmuehlen PC. Polymer-infiltrated ceramic CAD/CAM inlays and partial coverage restorations: 3-year results of a prospective clinical study over 5 years. Clin Oral Investig. 2017 Dec 6. doi: 10.1007/s00784-017-2293-x. [Epub ahead of print]

30. Rusin RP. Properties and applications of a new composite block for CAD/CAM. Compend Contin Educ Dent. 2001 Jun;22(6 suppl):35-41.

31. Fasbinder DJ, Neiva GF, Dennison JB, Heys DR. Clinical performance of CAD/CAM-generated composite inlays after 10 years: comparing the longitudinal performance of composite and porcelain. J Cosmetic Dent. 2013 Winter; 28(4):134-45.

32. Guazzato M, Albakry M, Ringer SP, Swain MV. Strength, fracture toughness and microstructure of a selection of all-ceramic materials. Part II. Zirconia-based dental ceramics. Dent Mater. 2004 Jun;20(5):449-56.

33. Vichi A, Sedda M, Fabian Fonzar R, Carrabba M, Ferrari M. Comparison of contrast ratio, translucency parameter, and flexural strength of traditional and "augmented translucency" zirconia for CEREC CAD/CAM system. J Esthet Restor Dent. 2016 Mar;28 Suppl 1:S32-9. **jCD**



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