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## **CLINICAL EFFICACY OF CEREC® 3 ALL-CERAMIC RESTORATIONS:**

*A 20-Year History of Peerless Performance*

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It is now nearly two decades after the market introduction of the CEREC System for the manufacture of all-ceramic dental restorations. CEREC can fabricate restorations for all single-unit clinical indications: inlays, partial crowns, crowns (posterior & Anterior), and veneers. With over 7,000,000 restorations placed since the introduction of CEREC technology in 1987, CEREC is one of the most researched restorative systems on the market, with documented success rates of more than 90% after 10 years. Unlike other indirect processes, CEREC restorations are milled from solid, homogenous blocks of all-

ceramic material. The production process for CEREC blocks ensures optimal consistency with very little variation in strength or quality. Ceramics used for CEREC restorations display enamel wear characteristics more comparable to natural tooth enamel than other materials. CEREC materials, manufactured by VITA, Ivoclar and 3M ESPE, are available in a wide array of shades and translucencies. The studies featured in this document highlight the exceptional clinical performance and longevity of CEREC all-ceramic restorations.

# FIT

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During the CEREC System's nearly 20-year history, there have been three generations of equipment. CEREC 1 was introduced in 1987 to produce inlays; CEREC 2 was launched in 1994 and ultimately offered all single units indications; and CEREC 3 was born in 2000, adding a 3-milling dimensional operating systems 2003. Given the product evolution timeline, it is obvious that most mid- and long-term studies focus on the CEREC 1 and CEREC 2 Systems. The studies below outline the clinical fit performance of these systems, and newer studies are showing even better results for CEREC 3D.

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*Gen Dent. 2003; 51(5)*

## **Scanning electron microscope evaluation of CEREC II and CEREC III inlays.**

Estafan D, Dussetschleger F, Agosta C, Reich S.

In response to an increased public demand for esthetic restorations, dentists are using computer-aided design/computer-aided manufacture (CAD/CAM) technology to fabricate inlay/onlay, crown, and laminate veneers. **This study evaluated the fit at the gingival margin of surface inlay restorations milled by the CEREC II as well as the recently developed CEREC III. The marginal fit of inlays milled by the CEREC III was more accurate than the fit of those milled by the CEREC II, although both were within the ADA specification of 50µ.**

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*Int J Prosthodont. 2003; 16(3): 244-248*

## **Marginal and internal fit of CEREC 3 CAD/CAM all-ceramic crowns.**

Nakamura T, Dei N, Kojima T, Wakabayashi K.

**PURPOSE:** The purpose of this study was to examine the effect of the occlusal convergence angle of the abutment and the computer's luting space setting on the marginal and internal fit of CEREC 3 computer aided design/manufacturing (CAD/CAM) all-ceramic crowns. **MATERIALS AND METHODS:** Mandibular second premolar all-ceramic crowns were fabricated for nine different conditions used CEREC 3: all combinations of abutment with three different total occlusal convergence angles (4, 8 and 12 degrees) with three different luting space settings (10, 30 and 50 microns). The complete crowns were seated on the abutments and the marginal gaps were measured. The internal gaps between the

crown and abutments were also measured, using test-fit silicone paste. **RESULTS:** When the luting space was set to 10 microns, the marginal gap of the crown were greater than when it was set to 30 or 50 microns. When the luting space was set to 30 or 50 microns, the **marginal gaps ranged from 53 to 67 microns and were not affected by the occlusal convergence angle of the abutment.** The internal gaps were within a range of 116 to 162 microns and tended to decrease as the occlusal convergence angle of the abutment decreased. **CONCLUSION:** When the luting space was set to 30 microns, **crown with a good fit could be fabricated on the CEREC 3 Systems, regardless of the occlusal convergence angle of the abutment.**

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*Eur J Oral Sci. 2003; 111(2): 163-169.*

## **Clinical and SEM evaluation of all-ceramic chair-side CAD/CAM-generated partial crowns.**

Bindl A, Mörmann WH.

The effect of hardware and software on the quality of CEREC all-ceramic partial crowns was investigated in this cross-sectional study. Partial crowns (n=818) had been adhesively placed in 496 patients between 1993 and 1997 using CEREC 1 and CEREC 2 (groups 1 and 2) as well as CEREC 2 with wall-spacing software (group 3). From each group, 25 randomly selected partial crowns were evaluated using modified United States Public Health Service (USPHS) criteria. Of these, 12 were randomly selected in each group, replicas taken and examined in a scanning electron microscope for marginal adaptation. Interfacial width of group 1 (308 +/- 95 microns) was significantly larger than those of groups 2 (243 +/- 48 microns) and 3 (207 +/- 63 microns). Continuous margin adaptation at the tooth-luting composite and luting composite-restoration interfaces showed only minor differences in group 1 (94.5 +/- 8% and 95.5 +/- 2%), 2 (98.1 +/- 1% and 97.5 +/- 1.4%) and 3 (96.8 +/- 3% and 96.8 +/- 2%). **Pooled clinical rating was excellent or good at 97% for all groups,** indicating acceptable restoration quality except for one breakage in group 1.

# LONGEVITY

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Many advances in dental technology have taken place since the introduction of CEREC in 1987. As CEREC has evolved, so have adhesive bonding techniques and methods. The studies below attest to the longevity of CEREC restorations. While these results attest to the longevity of CEREC, it is important to note that improvements in both CEREC technology and bonding techniques promise to produce even better results for restorations being placed today and in the future.

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*Int J Comput Dent 2003; 6(3): 231-248*

## **Longevity of 2328 chairside CEREC inlays and onlays.**

Posselt A, Kerschbaum T.

**In a dental practice, 2328 ceramic inlays were placed in 794 patients. The restorations were manufactured chairside using CEREC technology and adhesively inserted at the same appointment. The clinical performance of the restoration was evaluated with Kaplan-Meier analysis. The probability of survival was 95.5% after 9 years;** 35 CEREC restorations were judged as failures. The prognosis for success was not significantly influenced by restorations size, tooth vitality, treatment of caries profunda (CP), type of tooth treated, or whether the restoration was located in the maxilla or mandible. The most common type of failure was the extraction of a tooth. In a clinical follow-up light-microscopic examination of 44 randomly selected restorations. And average composite joint width of 236.3 microns was found. 45.1% of the restoration exhibited a perfect margin and 47.4% of the investigated joint sections showed underfilled margins.

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*Int J Prosthodont. 2002; 15(2) 122-128*

## **Computer-aided direct ceramic restorations: a 10-year prospective clinical study of CEREC CAD/CAM inlays and onlays.**

Otto T, De Nisco S.

**PURPOSE:** The objective of this follow-up study was to examine the performance of CEREC inlays and onlays in terms of clinical quality over a functional period of 10-years. **MATERIALS AND METHODS:** Of 200 CEREC inlays and onlays placed in a private practice between 1989 and early 1991, 187

restorations were observed over a period of 10 years. The restorations were fabricated chairside using the CEREC-1 computer-aided design/manufacturing (CAD/CAM) method and Vita MK I feldspathic ceramic. An adhesive technique and luting composite resin were used for seating the restoration. After 10 years, the clinical performance of the restoration was evaluated using modified USPHS criteria. The results were used to classify success and failure. **RESULT:** According to Kaplan-Meier analysis, the success rate of CEREC inlays and onlays dropped to 90.4% after 10 years. A total of 15 (8%) failures were found in 11 patients. Of these failures, 73% were caused by either ceramic fracture (53%) or tooth fracture (20%). The reasons for the remaining failures were caries (20%) and endodontic problems (7%). The tree-surface CEREC reconstructions were found to have the most failures. **CONCLUSION:** The failure rate of 8% and the drop of the survival probability rate to 90.4% after 10 years of clinical service of CEREC-1 CAD/CAM restoration made of Vita MK I feldspathic ceramic appear to be acceptable in private practice. This is particularly true in light of very high patient satisfaction.

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*J Adhes Dent. 2001; 3(1): 45-64*

## **Longevity of restoration in posterior teeth and reasons for failure.**

Hickel R, Manhart J.

**PURPOSE:** This article compiles a survey on the longevity of restorations in stress-bearing posterior cavities and assesses possible reason for failure. **MATERIALS AND METHODS:** The dental literature predominantly of the last decade was reviewed for longitudinal, controlled clinical studies and respective cross-sectional studies of posterior restorations. Only studies investigating the clinical performance of restorations in permanent teeth were included. Longevity and annual failure rates of amalgam, direct composite and ceramic inlays, and cast gold restorations were determined for class I and II cavities. **RESULTS: Annual failure rates in posterior stress-bearing restorations are 0% to 7% for amalgam restorations, 0% to 9% for direct composites, 1.4% to 14.4% for glass ionomers and derivatives, 0% to 11.8% for composite inlays, 0% to 9% for composite inlays, 0% to 7.5% for ceramic restorations, 0% to 4.4% for CAD/CAM ceramic restorations and 0% to 5.9% for cast gold inlays and onlays.** **CONCLUSION:**

Longevity of dental restoration is dependent upon many different factors that are related to materials, the patient, and the dentist. The principal reasons for failure were secondary caries, fracture, marginal deficiencies, wear, and postoperative sensitivity. A distinction must be made between factors causing early failures and those that are responsible for restoration loss after several years of service.

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*J Adhes Dent.* 1999; 1(3): 255-265

**Clinical evaluation of adhesively placed CEREC endo-crowns after 2 years – preliminary results.**

Bindl A. Mörmann WH.

**PURPOSE:** Non-vital endodontically treated posterior teeth with complete loss of coronal hard tissues were prepared with a circular equigingival butt margin and central retention cavity of the entire pulp chamber (“endo-preparation”). Computer-generated ceramic coronal-radicular restorations (CEREC endo-crown) were bonded to these preparations. The purpose of this study was to evaluate the survival rate and the clinical quality of CAD/CAM endo-crowns after 2 years. **MATERIALS AND METHODS:** 19 CEREC endo-crowns (4 premolars and 15 molars) in 13 patients were examined using modified USPHS criteria at baseline and after an average time of 26 months. The rating of the two examinations were compared. **RESULTS:** The service time of the 19 endo-crowns was 14 to 35.5 (mean +/- SD: 26 +/- 6) months. One molar endo-crown failed after 28 months because of recurrent caries. **CONCLUSION:** The overall clinical quality of the CEREC endo-crown was very good, and so far, the clinical concept appears feasible.

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*Dent Mater.* 1999; 15(1):54-61

**Clinical performance of CEREC ceramic inlays: a systematic review.**

Martin N. Jedynekiewicz NM.

**OBJECTIVE:** This systematic review of clinical trials seeks to identify the clinical performance of intra-coronal CEREC restorations luted with an adhesive composite technique. The focus of the review is to establish the survival rate of these restorations and to identify the factors that may cause them to fail. **METHOD:** A comprehensive literature search was undertaken, spanning from the year of introduction of the technology – 1986 to 1997. This review identifies

universal indicators of the clinical performance of intra-coronal CEREC restorations luted with an adhesive composite technique. Throughout the critical appraisal, each individual study was analysed identifying the aims, the methodology and materials used and the results obtained. **RESULTS:** 29 clinical reports were identified in the search. The systematic analysis reduced the focus of the review to 15 studies. **The data available establishes ceramic intra-coronal restoration machined by CEREC Systems as a clinically successful restorative method with a mean survival rate of 97.4% over a period of 4.2 years.** The review also highlighted the reasons and the rates of failure for this type of restoration. The predominant reason for failure are fractures of the ceramic, fracture of the supporting tooth, postoperative hypersensitivity and wear of the interface lute. **SIGNIFICANCE:** Machinable ceramic, as used by the CEREC System, provide a useful restoration with a high success rate. These restorations are colour-stable and wear at a clinically acceptable rate. Wear of luting composite on occlusal surface leads to interface and post-operative hypersensitivity remain a problem which requires further investigation.

## STRENGTH

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Indirect all-ceramic restorations have proven to be strong, reliable restorative techniques. However, it is difficult to reproduce exceptional strength and composition through traditional means. CEREC materials are different. They are industrially manufactured under controlled conditions and are pre-sintered. This ensures that the ceramic blocks have consistent particle size, porosity and strength throughout. The evaluations below highlight the strength inherent in material used for CEREC restorations.

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*Am J Dent.* 2001; 14(4): 216-220

**Molar fracture resistance after adhesive restoration with ceramic inlays or resin-based composites.**

Bremer BD, Geurtsen W.

**PURPOSE:** To determine the fracture resistance of teeth, following treatment with various types of adhesive restorations. **MATERIALS AND METHODS:** 50 caries-free, extracted human molars were randomly divided into five groups consisting of 10 molars each. MOD cavities were prepared in

40 molars with a width in the facio-lingual direction of 50% of the intercusp distance. The cavities were filled with the following materials: CEREC or IPS Empress ceramic inlays, Arabesk or Charisma F resin-based composite (RBC) restorations. The control group consisted of 10 sound, non-restored molars. All 50 teeth were loaded occlusally until fracture using a tensile testing machine. The statistical analysis included ANOVA, Kolmogorov-Smirnov test, Scheffe test, and boxplots. RESULTS: There was no significant difference ( $P > 0.05$ ) between the mean values of the sound teeth (2,102 N) and the teeth with the CEREC ceramic inlays (2,139 N). However, both groups demonstrated a significant difference ( $P < 0.05$ ) when compared with the teeth with IPS Empress ceramic inlays (1,459 N) and Arabesk RBC restorations (1459 N).

No significant difference were found between the last two groups. Molars restored with Charisma F composite restorations (1,562 N) revealed no significant difference when compared with all other groups including controls ( $P > 0.05$ ). A stabilization of molars is possible by means of an adhesive restoration in the form of an "internal splinting" regardless of the restorative materials used.

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*J Dent.* 2000; 28(7): 529-535

#### **Structural reliability of alumina-, feldspar-, leucite-, mica-, and zirconia-based ceramics.**

Tinschert J, Zvez D, Marx R, Anusavice KJ.

OBJECTIVES: The objective of this study was to test the hypothesis that industrially manufactured ceramic materials, such as CEREC Mark II and Zirconia-TZP, have a smaller range of fracture strength variation and therefore greater structural reliability than laboratory-processed dental ceramic materials. METHODS: Thirty bar specimens per material were prepared and tested. The four-point bend test was used to determine the flexure strength of all ceramic materials. The fracture stress values were analysed by Weibull analysis to determine the Weibull modulus values ( $m$ ) and the 1 and 5% probabilities of failure. RESULTS: The mean strength and standard deviation values for these ceramic are as follows: (MPa $\pm$ SD) were: CEREC Mark II, 86.3 $\pm$ 4.3; Dicor 70.3 $\pm$ 12.2; In-Ceram Alumina, 429.3 $\pm$ 87.2; IPS Empress, 83.9 $\pm$ 11.3; Vitadur Alpha Core, 131.9 $\pm$ 10.0; and Zirconia-TZP, 913.0 $\pm$ 50.2. There was no statistically significant difference among the flexure strength of CEREC Mark II, Dicor, IPS

Empress, Vitadur Alpha Dentin, and Vita VMK 68 ceramics ( $p > 0.05$ ). The highest Weibull moduli were associated with CEREC Mark II and Zirconia-TZP ceramics (23.6 and 18.4). Dicor glass-ceramic and In-Ceram Alumina had the lowest  $m$  value (5.5 and 5.7) where-as intermediate values were observed for IPS Empress, Vita VMK 68, Vitadur Alpha Dentin and Vitadur Alpha Core ceramic (8.6, 8.9, 10.0 and 13.0, respectively). CONCLUSIONS: Except for In-Ceram Alumina, Vitadur Alpha and Zirconia-TZP core ceramics, most if the investigated ceramic materials fabricated under the condition of a dental laboratory were not stronger or more structurally reliable than Vita VMK 68 veneering porcelain. **Only CEREC Mark II and Zirconia-TZP specimens, which were prepared from an industrially optimized ceramic material, exhibited  $m$  values greater than 18. Hence, we conclude that industrially prepared ceramics are more structurally reliable materials for dental applications** although CAD-CAM procedures may induce surface and subsurface flaws that may adversely affect this property.

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*J Prosthet Dent.* 1999; 82(4): 468-475

#### **Effects of surface finish and fatigue testing on the fracture strength of CAD-CAM and pressed-ceramic crowns.**

Chen HY, Hickel R, Setcos JC, Kunzelmann KH.

STATEMENT OF PROBLEM: All-ceramic molar crowns can be fabricated with CAD-CAM or laboratory methods with different material, and a polished or oven-glazed surface. PURPOSE: This in vitro study determined the fracture strength of various all-ceramic crowns, with and without prior cyclic loading. MATERIAL AND METHODS: Standardised molar crowns were fabricated with a CAD-CAM machine (CEREC 2), software with machinable ceramic materials (Vita Mark II and ProCAD), and also conventional heat-pressed IPS Empress crowns fabricated at 2 dental laboratories. Groups of 40 crowns of each material were manufactured with either a polished or an oven-glazed surface finish. Cyclic loading that simulated oral conditions were performed on half of each group. Afterward, all crowns were loaded until catastrophic failure. RESULTS: Fracture loads of the polished ProCAD crowns without prior cyclic loading was 2120  $\pm$  231 N, significantly higher than that of the polished Vita Mark II crowns (1905  $\pm$  235 N), but was not significantly different from the strength of 2 laboratory-fabricated Empress crowns.

Oven-glazing of ProCAD crowns improved the fracture strength significantly, up to 2254 +/- 186 N. Prior cyclic loading decreased the strength of all tested crowns significantly, but the reduction was less for the CEREC crowns than the Empress crowns. **CONCLUSION:** CEREC ProCAD crowns demonstrated significantly greater strength than the Vita Mark II crowns better resistance to cyclic loading and lower failure probability than the laboratory-fabricated IPS Empress crowns. Prior cyclic loading significantly reduced the strength of all-ceramic crowns, but has less effect on CEREC crowns than on the IPS Empress crowns. Oven-glazing of ProCAD crowns resulted in significantly higher strength and higher resistance to cyclic loading than surface polishing.

## WEAR CHARACTERISTICS

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In addition to being well-fitting, long-lasting, and strong, CEREC restorations have among their qualities enamel-like wear characteristics. Enamel wears at different rates against different restorative materials. The studies below illustrate how CEREC ceramic are less abrasive to opposing dentition than other restorative options.

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J Dent. 1998; 26(5-6): 487-495

### **Investigation of human enamel wear against four dental ceramic and gold.**

Al-Hiyasat AS, Saunders WP, Sharkey SW, Smith GM, Gilmour WH.

**OBJECTIVES:** This in vitro study compared the wear of enamel against aluminous porcelain, bonded porcelain, low fusing hydrothermal ceramic, feldspathic machinable ceramic, and cast gold. **METHODS:** Fifty pairs of tooth-material specimens were tested in a dental wear machine, under a standard load (40 N), rate (80 cycles min<sup>-1</sup>) and for 25,000 cycles in distilled water. The amount of wear was determined by measuring the height loss of tooth, and the depth of wear track of the restorative materials. **RESULTS:** There was a significant difference in wear among the group for both enamel and materials ( $p < 0.001$ ). Follow-up comparisons (95% CI significant level) showed that gold caused significantly less enamel wear than all ceramics tested. The amount of enamel wear in aluminous and bonded porcelain groups was significantly higher than with the hydrothermal and machinable ceramic groups. There was no

significant difference between the amount of enamel wear produced by the aluminous and bonded porcelain nor between that produced by the hydrothermal and machinable ceramics. Furthermore, the wear of the aluminous and bonded porcelains was significantly greater than that of the hydrothermal ceramic, the machinable ceramics and gold. No significant difference in wear was found between aluminous and bonded porcelains, hydrothermal and machinable ceramics or between machinable ceramic and gold. However, the hydrothermal ceramic had significantly greater wear than gold. **CONCLUSIONS:** It was concluded that the hydrothermal and the machinable ceramics were significantly less abrasive and more resistant to wear than the conventional aluminous and bonded porcelains. Gold was the least abrasive material and most resistant to wear, although the difference in wear between the machinable ceramic and gold was not statistically significant.

## POST-OPERATIVE SENSITIVITY

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Patients request CEREC restorations for many reasons: long-lasting, single-appointment convenience, tooth-coloured, biocompatibility, etc. Another benefit of CEREC materials is the documented lack of post-operative sensitivity. Satisfied patients provide quality referrals and are more likely to accept future treatment plans.

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*CRA Newsletter. 1999; 23(11): 2.*

### **Post-op sensitivity related to type of restoration and material.**

Data from 8 different CRA clinical studies conducted over 11 years were compiled in this study. Approximately 45 restorations each of 31 materials brands were placed by about 20 different dentists in each of the studies. **CEREC inlay/onlay restorations machined from Vita Mark II feldspathic porcelain showed 0% post-operative sensitivity.**