Scientific Studies (Vol. II)

Cercon smart ceramics – the zirconia all-ceramic system
Overview of Current Cercon Research

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Over the last years, zirconium oxide has become indispensable for all-ceramic dental restorations. The development of a practicable method for processing partially yttria-stabilized zirconium oxide in the dental lab now allows the everyday application of this technology. The CAM system Cercon smart ceramics is based on the research and the know-how of the teams at the Technical University and the Dental Clinic in Zurich/Switzerland. Today, this system is the globally leading CAM system in dentistry – by its degree of innovation as well as by the numbers of units sold. Only five years after the launch, more than 1.5 million zirconium oxide restorations have been produced with Cercon smart ceramics.

A close continued cooperation with renowned scientists and universities guarantees the constant further development and expanded range of indications of this innovative system which has been evaluated and controlled in clinical studies since 1998. More than seven years of clinical evaluation prove the excellent material properties of zirconium oxide frameworks for crowns and multi-unit FPDs in the anterior and posterior region.

The well-established ranges of application and possible new indications for this material, e.g. cantilever fixed partial dentures, inlay bridges or multi-unit bridges, are continuously evaluated in in-vitro tests and clinical studies. Currently, more than 1,000 restorations are under observation in more than 10 clinical studies.

Due to its long-term clinical performance, Cercon smart ceramics has become the reference technology for alternative all-ceramic production techniques. Moreover, the rapid development in computer hardware and software provides for new impulses in the progress of processing zirconium oxide: The original CAM system Cercon smart ceramics has in the meantime been rounded off by components required for a CAD (Computer-Aided Design) modelling of frameworks.

Cercon smart ceramics now is the only system which offers both possibilities – the conventional wax modelling as well as the use of CAD for the framework design. New components like the CAD modulus Cercon art or the desktop scanner Cercon eye are a consequent continuation of the innovative Cercon technology for the processing of all-ceramic materials in dentistry.

The present bibliography offers an actual survey on the results of relevant material-science and clinical studies on Cercon smart ceramics. It has been compiled to serve as an orientation for your daily work in the practice and in the dental lab.
Degussa Dental GmbH (now DeguDent GmbH) purchased the rights of the DCM procedure and, in close cooperation with the two Zurich teams, developed the Cercon smart ceramics system based on the DCM system. The fitting accuracy was significantly improved by DeguDent’s development of the hardware and software for the combined scanning and milling unit (Cercon brain). Moreover, a new veneering porcelain (Cercon ceram S, Cercon ceram kiss) was developed which is especially suitable for Cercon base Y-TZP frameworks.

Zirconia – or more precisely: Y-TZP (yttrium-stabilized tetragonal zirconia polycrystals) – undeniably possesses the highest flexural and fracture strength of all dental ceramics currently available. Zirconia is even suitable for long-span restorations in the posterior region. Y-TZP is a well-established material in medicine for the manufacture of hip joints. However, a few technical hurdles in the machining process had to be overcome before this high-strength ceramic material could be applied in dentistry.

In the beginning, attempts were made to prepare zirconia in the sintered state. As the material is exceptionally hard, this did not only require high expenditures for equipment but also led to lengthy processing times.

A team headed by Professor Dr Ludwig Gauckler at the ETH Zurich (Swiss Federal Institute of Technology) developed a procedure for preparing pre-sintered zirconia. In cooperation with the dental team headed by Professor Dr Peter Schärer at the University of Zurich, this led to the development of the DCM system (Direct Ceramic Machining) for dentistry. This system allowed for a cost-effective fabrication of crown and bridge frameworks in the dental laboratory. The Dental School at the University of Zurich has been fitting long-span bridges during a controlled prospective clinical study on the DCM system since 1998.

The zirconia frameworks exhibited an exceptional breaking strength. This study also indicated, however, that the DCM system still required improvement regarding the fitting accuracy of the frameworks and the veneering porcelain.

Fitting Accuracy:
Marginal and Internal Fit of CAM-Milled Zirconia Crowns


Objective:
The present in-vitro study examines the marginal and internal fit of zirconia crown frames with preparation angle $\alpha/2 = 6^\circ$ and compares findings of the old and the new CAM-software. The difference between adapted and non-adapted crowns was analysed also. The non-adapted crown frames should reflect the CAM-system’s precision and indicate whether adaptation by the dental technician is necessary.

Method:
The crown frames were manufactured by the CAM-system Cercon (DeguDent, Hanau/Germany) on 40 different master dies with preparation angle $\alpha/2 = 6^\circ$. 20 crown frames were milled by the old CAM-software, 20 by the latest software update. In each case 10 crowns were coincidentally selected and adapted by the dental technician to the optimum fit. The time needed for adaptation was noted. All 40 crown frames were fixed on the master dies by glass ionomer cement. The fixed crown frames were cut parallel to the milling direction and examined by the scanning electron microscope (Stereoscan 250 Cambridge, Leica, Wetzlar/Germany).

The average marginal fit shows 50.7 µm for adapted crown frames of the old software and 40.3 µm for the updated software. A significant difference between old and new software and adapted and non-adapted crown frames exists (Mann-Whitney-U-test, $p < 0.05$). The crowns manufactured by the old software show a broad dispersion in the range of the cement layer from 15 µm to 560 µm (adapted crown frames) and from 5 µm to more than 1,380 µm for the non-adapted crown frames. The adapted crowns milled by new software get a thin equalised cement layer.

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Conclusions:

To conclude, the new software compensates more exactly for the zirconia blanks’ shrinkage of sinter. The marginal and internal fit is significantly improved. An adaptation by the dental technician is still necessary.

This study continues the already published study on the influence of the preparation angle on the fitting accuracy which is summarized here:

**Marginal and internal fit of CAM-milled zirconia single crown frameworks at different preparation angles**


The present in-vitro study on the all-ceramic zirconium milling system Cercon smart ceramics (DeguDent GmbH) evaluates which preparation angle a/2 leads to the best results for the marginal gap and the internal fitting accuracy. The crown frames were manufactured on a total of 60 master dies with different convergence angles a/2 (2°, 4°, 6°). A dental technician adapted 30 of the frames until the optimum fit was achieved; the other 30 frames remained unadapted, they were cemented to the master die and cut. The marginal and internal fit was evaluated by SEM. The mean values for the marginal gaps of the adapted frames at convergence angles a/2 of 6°, 4°, and 2° were determined at 50.7 µm, 56.0 µm, and 72.7 µm, all being within the clinically tolerable range. The study proves that the Cercon system is calculating the shrinkage of the zirconia blanks during the sintering process exactly. Thus a consistent cementation gap for the adapted crown frames is achieved.

Note:

Summary:

Re-working time in min

<table>
<thead>
<tr>
<th>N = 10</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>New time</td>
<td>Time</td>
</tr>
</tbody>
</table>

Evaluation of the required adaptation times for the crowns with a significant reduction due to the use of the new software (new time)

The box contains 50% of the data; it is limited on top and below by the 25% quantile. The median (50% of the measurements are above resp. below this value) is shown as a crossbar.
All-ceramic materials are used because of their good aesthetics and biocompatibility. High mechanical strength makes zirconia a suitable material for fixed partial dentures in posterior regions. Most of the common zirconia systems offer white opaque frames and so the esthetic advantage of an all-ceramic restoration is decreased. The LAVA-system (3M-Espe/Seefeld, Germany), which is milling presintered zirconia, colors the frames before sintering and gets colors very close to natural dentin. Dental technicians use this coloring solution also for other systems milling presintered zirconia. The Cercon smart ceramics System (DeguDent, Hanau/Germany) offers presintered colored zirconia blanks to advance the esthetics.

This study examined the influence of the coloring solutions on the flexural strength of zirconia. Another major point is the aging of colored and white zirconia, which is also analysed.

There were 60 round samples of presintered zirconia which were distributed the following way. 20 white samples were prepared according to the manufacturer, 20 colored by LAVA-frameshade solution, 20 pre-colored samples whereof 10 in each case were artificially aged over a fictive period of 5 years. All samples fulfilled the requirements of the standard EN ISO 6782, this experimental setup makes it possible to calculate the flexural strength out of the failure force.
The best performance before aging did the white zirconia with an average flexural strength of 1,320 MPa, the best aged zirconia is the precolored zirconia showing 1,184 MPa. It’s also remarkable that the colored zirconia loses almost no flexural strength after artificial aging. The Weibull module is also increased by coloring the zirconia framework.

Colored zirconia-frames should be used because the reliability and the flexural strength after artificial aging are significantly better than white zirconia frames. Their better performance may underlie in tighter mesh structure because the metal oxide frameshade is between the zirconia molecules.
Objective:
The purpose of this study was to compare the marginal fit of the anterior single restorations made using computer-aided milled Cercon crowns with metal-ceramic restorations and to obtain more accurate information by using a large enough sample size and by making sufficient measurements per specimen.

Method:
The in-vitro marginal discrepancies of computer-aided milled Cercon crowns and control groups (metal ceramic crowns) were evaluated and compared. The crowns were made from one extracted maxillary central incisor prepared by milling machine. 30 crowns per each system were fabricated. Measurements of a crown were recorded at 50 points that were randomly selected for marginal gap evaluation. Parametric statistical analysis was performed for the results.

![Fitting accuracy of the evaluated specimens in μm](image-url)
The means and standard deviations of the marginal fit were 85 ± 22 µm for the control group, and 91 ± 15 µm for the Cercon crowns.

The Cercon crowns showed slightly larger marginal gap discrepancy than the control but marginal gap between computer-aided milled Cercon crowns and metal ceramic crowns did not show significant differences (P = .05).
In-Vitro Fracture Resistance of Posterior Metal-Ceramic and All-Ceramic Inlay-Retained Resin-Bonded Fixed Partial Dentures

Klicarslan M.A., Kedici P.S., Küçükesmen H.C., Uludag B.C.
Ankara, Turkey (2004)

Inlay-retained resin-bonded fixed partial dentures (RBFPDs) are conservative prosthetic restorations; however, their resistance to fracture is not clear.

The purpose of this study was to compare fracture loads of posterior complete coverage metal-ceramic restorations with all-ceramic inlay-retained RBFPDs.

Thirty-two posterior ceramic RBFPD restorations were divided into 4 groups (n = 8): (1) Complete metal-ceramic fixed partial dentures (MC-FPDs) fabricated of NiCr-based alloy (Wirolloy, Bego, Bremen) and veneered with a ceramic (IPD d.SIGN) as the control group; (2) inlay-retained metal-ceramic (MC RBFPDs) with the same materials as the control; (3) inlay-retained lithium disilicate (LD) glass-ceramic (IPS Empress 2) RBFPDs; and (4) inlay-retained zirconia-based (Z) Ceramic (Cercon) RBFPDs. Control specimens were prepared to receive conventional complete MC-FPDs designed to include a 1.3 mm circumferential, 90 degree flat shoulder with rounded angles. Inlay-retained RBFPD specimens were prepared with 2 mm occlusal reduction but without bevels at the occlusal or gingival margins. Specimens were loaded and fracture loads (N) measured at fracture with a universal testing machine at a crosshead speed of 1.0 mm/min and 250 kgf load cell. Data were analyzed with one-way ANOVA and Duncan test (p < 0.01).
Fracture loads (mean ± SD) were greatest for control specimens (1,318.43 ± 211.00 N) and Z-RBFPD (1,247.70 ± 262.51 N) specimens as compared to MC-RBFPD or LD-RBFPD (p < 0.01). MC-RBFPD exhibited the next highest fracture loads (958.01 ± 194.29 N), and LD-RBFPD exhibited the significantly lowest values (303.23 ± 92.54 N) of the materials tested (p < 0.01).

Inlay-retained zirconia-based ceramic RBFPDs demonstrated the greatest fracture resistance among all inlay-retained restorations tested.

The results of this in-vitro study suggest that adhesively bonded inlay FPDs offer a substance-sparing prosthetic treatment if an adequate material is chosen. When compared with metal-ceramic and all-ceramic inlay FPDs made of lithium-disilicate ceramics, zirconium-based inlay FPDs revealed the highest mean values of fracture strength.
Objective: The objective of this in-vitro study was to investigate the bond strength of two ceramics bonded to yttria-stabilized tetragonal zirconia (Y-TZP) frameworks.

Method: Twenty-four Y-TZP frameworks (25 x 3 x 0.5 mm) were fabricated by a CAM-aided system (Cercon smart ceramics, DeguDent) and divided into four groups. In two groups, the surfaces of the Y-TZP frameworks were polished with 600 grit SiC paper. The framework surface was sandblasted with 100 µm alumina particles. Two types of ceramics specially developed for zirconium oxide, Cercon ceram S (DeguDent) and Cerabien ZR (Noritake) were applied and adjusted to a final thickness of 1.5 mm including the Y-TZP frameworks according to DIN 13 927. The specimens were subjected to a three-point bending test using a universal testing machine (1123 Instron). The data (mean ± SD, MPa) were analyzed by one-way ANOVA and Tukey HSD test (p < 0.05).

[Graph: Compound strength evaluated with the three-point bending test (Schickerath test) for the 2 zirconium oxide veneering ceramics examined]
Results:

The surface roughness of the Y-TZP frameworks with and without polishing with 600 grit SiC paper were Ra 2.82 ± 0.576 µm and Ra 0.720 ± 0.142 µm respectively. The bond strengths of Cercon ceram S and Cerabien ZR to Y-TZP frameworks (without polishing) were 40.1 ± 8.7 and 27.5 ± 3.4 MPa respectively. The bond strengths of Cercon ceram S and Cerabien ZR to Y-TZP frameworks polished with 600 grit SiC paper were 45.2 ± 8.7 and 30.6 ± 3.6 MPa respectively. There were significant differences between Cercon ceram S and Cerabien ZR (p < 0.05).

Conclusions:

The results showed that Cercon ceram S and Cerabien ZR were suitable ceramics for Y-TZP.
Fracture Strength of Zirconia Posterior Fixed Partial Dentures

Rosentritt M., Behr M., Kolbeck C., Handel G.
Regensburg, Germany (2004)

The aim of this in-vitro study was to determine the fracture strength of tooth colored zirconia fixed partial dentures (FPDs) with a different kind of cementation.

96 human molars were inserted in PMMA resin to create a three-unit (10 mm) oral situation. The roots of the teeth were covered with an about 1 mm thick layer of polyether to simulate the periodontium. 2x 8 bridges of each series were made of the zirconia materials and fixed with an adhesive bonding system (Syntac classic/Variolink2; Ivoclar-Vivadent, FL) and recommended conventional cementation: A) Digizon/GC Initial (Fuji Plus, Girrbach, G), B) Lava/Lava Ceram (Ketac Cem, 3M Espe, G) and Cercon/Cercon Ceram (Harvard, DeguDent, G). After thermal cycling and mechanical loading (TCML; 6,000 thermal cycles [5°C/55°C] and 1.2 x 10^6 mastication cycles [50N]) fracture strengths (UTM 1446; Zwick; v = 1 mm/min) of 8 FPDs of each series were determined. Statistical analysis was performed with the Mann-Whitney U-test (p = 0.05).

<table>
<thead>
<tr>
<th>Fracture Force [N]</th>
<th>Digizon</th>
<th>Lava</th>
<th>Cercon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cementation:</td>
<td>Variolink</td>
<td>Fuji Plus</td>
<td>Variolink</td>
</tr>
<tr>
<td>Median</td>
<td>843</td>
<td>1,332</td>
<td>992</td>
</tr>
<tr>
<td>25 % percentile</td>
<td>738</td>
<td>1,131</td>
<td>815</td>
</tr>
<tr>
<td>75 % percentile</td>
<td>945</td>
<td>1,474</td>
<td>1,596</td>
</tr>
</tbody>
</table>
Conclusions:

There were no statistical differences between the different zirconia FPDs with conventional cementation. All FPDs showed lower fracture results with adhesive bonding, but only for Digizon the difference was statistically significant. The fracture forces of all zirconia FPDs were at a level where clinical application in posterior areas seems promising.

Box plot diagram of the fracture strength values for the 3 evaluated zirconium oxide systems

The box contains 50% of the data; it is limited on top and below by the 25% quantile. The median (50% of the measurements are above resp. below this value) is shown as a crossbar.
Effect of Shoulder Design on Failure Load of PTCercon Crowns


Objective:
To evaluate the effect of shoulder design on the failure load of Press-to-Cercon (PTC) crowns.

Method:
Two groups were studied: Overpressed crowns with a zirconia-free PTC shoulder (CS) and overpressed crowns with zirconia up to the margin (CC). The zirconia-free shoulder extended 0.8 mm over the finishing line of the coping. Eight zirconia copings per group of first maxillary anteriors were fabricated with Cercon Brain CAM system (DeguDent). The thickness was 0.6 mm standard. After milling, the copings were sintered at 1,350 °C to final density. After sintering the coping was waxed-up to a standard contour, sprued and invested in CarraraUniversalDustless Investment (Elephant). The PTC Ceramic was pressed at 940 °C over the zirconia coping. After devesting and separation from the sprues the crowns were veneered with two layers Cercon ceram S porcelain (DeguDent). The crowns were cemented on a CoCr die with zinc phosphate cement and held under constant load of 5 kg during setting. The crowns were inspected using SEM for surface fracture analysis. Failure loads were measured using vertical compression loading at 0.5 mm/min.

Results:
Failure loads [kN (SD)]: Group CS: 4,228 (515) and group CC: 5,408 (806).
Conclusions:

A significant (p < 0.05) decrease of 22 percent in breaking strength was observed with the overhanging shoulder as compared to fully supported PTC Crowns. Surface fracture analysis revealed the crack initiation site was typically located on the inside of the coping at the glass-zirconia interface.

![Graph showing static fracture strength comparison between Y-TZP margin with Group CS and Ceramic shoulder with Group CC.](image)
Objective:
The purpose of this study was to determine the in-vitro load bearing capacity of four-unit posterior frameworks made of glass ceramic with lithium-disilicate crystals (E2), of zirconia-reinforced glass-infiltrated alumina (ICZ), and of zirconia stabilized with 3 mol % yttria (CEZ).

Method:
All frameworks mimicked a four-unit posterior situation with 7.3 mm² interdental cross-sections and possessed exactly the same dimensions. The load bearing capacity was measured on a special bridge test setup with 15 specimens for each of the materials. The data were analyzed with Weibull statistics giving the characteristic load bearing capacity $F_0$ at 63 % failure probability and the Weibull modulus $m$ as indicator for the reliability and reproducibility.
Significance:

CEZ frameworks showed the best mechanical properties as demonstrated by the high values of average load bearing capacity, reliability, and characteristic load bearing capacity with respect to the other ceramics studied. However, for four-unit posterior CEZ frameworks the connector size of 7.3 mm² is insufficient to withstand occlusal forces reported in the literature. Four-unit posterior frameworks require a connector size larger than 7.3 mm².

Results:

For the E2 frameworks the average load bearing capacity and the SD was 260 (± 53) N, the characteristic load $F_0$ 282 N, and the reliability $m = 5.7$. For the ICZ frameworks the average load bearing capacity was 470 (± 101) N, $F_0$ 518 N, and $m = 4.5$. CEZ frameworks revealed the highest average load bearing capacity of 706 (± 123) N, the highest characteristic load bearing capacity $F_0 = 755$ N, and the best reliability $m = 7.0$. 

![Fracture strength of the evaluated 4-unit all-ceramic FPDs](image-url)
The aim of this study was to compare the static and fatigue fracture strength of 3-unit inlay-retained posterior FPDs using CAD/CAM-manufactured zirconia frameworks (Cercon, DeguDent, Hanau, Germany) and a lithium-disilicate based glass-ceramic (VP2563, Ivoclar, Schaan, FL).

Posterior teeth (25, 27) were prepared with mesial-occlusal and occlusal-distal cavities with proximal connectors of 9 mm² and 16 mm² respectively and were cast in a cobalt-chromium alloy. Sixty-four casts with resilient supported metal-dies were fabricated. Sixteen FPDs each were made with connector areas of 9 and 16 mm² for both ceramic systems. All FPDs were cemented with a composite resin (Multilink, Ivoclar). The static fracture resistance was tested in a universal testing machine (Zwick, Neu-Ulm, Germany) at the center of the pontic for six FPDs of each group. In the fatigue tests four FPDs of each group were treated with cyclic loading at 250 N using a chewing simulator (Willitec, Munich, Germany) and six FPDs each at 600 N using the universal testing machine.
For the static fracture strength means (Cercon at 9 mm$^2$ 3,244 ± 565 N, at 16 mm$^2$ 3,065 ± 260 N and VP2563 at 9 mm$^2$ 947 ± 196 N, at 16 mm$^2$ 1,385 ± 216 N) were significantly different for both systems (ANOVA, p < 0.05). Also the numbers of load cycles for first fracture events at 600 N showed significant differences. At 250 N FPDs made of Cercon did not fracture over 1,200,000 load cycles. FPDs made of VP2563 with a connector area of 9 mm$^2$ fractured at a mean of 986,000 loading cycles and with an area of 16 mm$^2$ at a mean of 1,150,000 cycles.

Considering the maximum chewing forces it seems possible to use Cercon for three-unit posterior inlay-retained FPDs. However, using VP2563, the connector area should have at least 16 mm$^2$. 

Fracture strength of the adhesively bonded inlay-retained FPDs, fabricated of 2 materials at different connector sizes
Objectives: The purpose of this laboratory study was to evaluate the influence of different cleaning methods after saliva contamination and after using a silicone disclosing medium on the resin bond strength to zirconia ceramic.

Methods: Plexiglas tubes filled with composite resin (Clearfil, Kuraray, J) were bonded to sandblasted zirconia ceramic discs (Cercon, DeguDent, Germany) using the phosphate monomer containing composite resin Panavia F2.0 (Kuraray, J). Four surface cleaning methods were used after contamination of the ceramic bonding surface with saliva and a silicone disclosing medium (Fit-Checker, GC, J): (A) cleaning in 96 % isopropanol for 15 s, (P1) cleaning with 37 % phosphoric acid for 60 s one time or (P2) for 30 s two times, or (S) sandblasting with 50 µm Al₂O₃ at 2.5 bars pressure for 15 s. The specimens of the control group (C) were not cleaned after using the silicone disclosing medium.

![Graph showing adhesive bond strength on contaminated zirconium oxide after different cleaning processes:](image-url)

Adhesive bond strength on contaminated zirconium oxide after different cleaning processes:
- **A**: Cleaning with 96 % isopropanol for 15 s
- **P1**: Cleaning with 37 % phosphoric acid for 1x 60 s
- **P2**: Cleaning with 37 % phosphoric acid for 2x 30 s
- **S**: Grit blasting with 50 µm Al₂O₃ (2.5 bar, 15 s)
- **Control**: No cleaning
In each group eight specimens were bonded in an alignment apparatus using the Panavia F2.0. Groups were stored for 3 days in tap water at 37 °C. Then the tensile bond strength was tested in a universal testing instrument (Zwick Z010/TN2A, Ulm, Germany) at 2 mm/min using an alignment which provided a moment-free axial force application.

The mean tensile bond strengths (TBS) in MPa were: (A) 8.2 ± 5.5; (P1) 23.6 ± 6.4; (P2) 37.2 ± 4.8; (S) 49.9 ± 7.4; (C) 6.6 ± 5.7. There were statistically significant differences among groups as revealed by the Kruskal-Wallis test (p < 0.001). Sandblasting of the ceramic surface provided statistically significantly higher TBS than the other cleaning methods. Cleaning in isopropanol did not improve TBS when compared to not cleaning at all.

Ceramic cleaning methods after try-in procedures have a significant influence on the resin bond strength. Sandblasting of zirconia ceramic is most effective.

Conclusions:
The increasing importance of zirconium oxide is mainly due to the demand for an increased stability of posterior FPDs. Zirconium oxide can be processed with numerous CAD/CAM and CAM systems, among them the Cercon System (DeguDent, Germany). The present study evaluates the long-term survival rate of 3- and 4-unit posterior FPDs which were produced with the Cercon System and were primarily cemented conventionally. The evaluation focuses on the following aspects: 1) stability of the framework ceramics, 2) durability of the veneering ceramics, and 3) applicability of a conventional cementation.

Material and methods:
Between January 2001 and February 2005, a total of 68 patients was treated with 84 3- and 4-unit posterior FPDs. 46 FPDs (group A) were veneered with an experimental veneering ceramic material; since the beginning of 2002, 38 FPDs (group B) were veneered with the now commercially available specially aligned veneering ceramic material Cercon ceram S. All inserted restorations were luted with zinc-phosphate cement. The standardized clinical evaluation was performed every 6 months according to partially modified CDA criteria. The mean observation period was 32 months.

Results:
Up to now, no fracture of a framework has been observed. A fracture and chipping of the veneering ceramic material was observed in 6 cases of group A, the restorations remained in situ after intraoral polishing. 7 cases of retention loss occurred, 5 restorations could be re-cemented, in 2 cases (both group A) the loosening had led to secondary caries and thus to a total loss. However, both patients concerned had not reneged on their recall appointments and only reappeared due to discomfort. In another case (group B), secondary caries on an endodontically treated abut-
Conclusions:

A restoration tooth led to the loss of the restoration. 3 cases were declared as total losses. 70 of 84 FPDs are still in situ without clinical intervention. The mean observation period of group A is 42 months (survival probability according to Kaplan-Meier: 82.7 %, n = 46). The mean observation period of group B is 21 months (survival probability according to Kaplan-Meier: 97.5 %, n = 38).

It can be stated that in comparison with the former experimental veneering ceramic material, the veneering ceramics Cercon ceram S shows an increased survival probability. The initial fitting quality of the frameworks can be rated good, a manual adaptation of the frameworks was hardly necessary. Considering the model analysis, the loss of retention was not explicitly due to a deficient preparation, it occurred mainly in the mandible (ratio 6:1). Here, an adhesive cementation is recommended – at least an adhesive re-cementation in cases with a loss of retention. Moreover, restorations with compromised clinical conditions (e.g. an abutment height of < 4 mm) should be observed at shorter recall intervals.
The aim of this clinical trial was to evaluate the clinical performance of zirconia-based implant abutments (Cercon Balance, Friadent, Germany) in a private practice.

From July 2001 to July 2003, 23 anterior implants (Ankylos, Friadent, Germany) placed in 14 patients (10 female/4 male) were restored with zirconia abutments (Cercon Balance, Friadent). All implants were restored with zirconia-based all-ceramic single crowns (Cercon, DeguDent, Germany). All crowns were luted with temporary cement (Temp-bond, Kerr Have, Germany) and evaluated according to modified Ryge criteria at baseline, after 6, 12 and 24 months.

All implants could be maintained without any clinically noticeable problems during this initial phase of clinical observation. The mean clinical observation period for the restorations was 625 days (± 179). During the evaluation period no fracture of a zirconia abutment or a screw loosening could be detected. Moreover, neither a loss of retention nor a fracture of a framework or chipping of the veneer porcelain was observed. The marginal integrity of the suprastructures was Alpha for 19 crowns and Bravo for 4 abutments. The color match and anatomic form was rated alpha for 22 restorations and Bravo for 1. The patient satisfaction with the level of functional rehabilitation was rated excellent by 10 and very good by 4 patients. The esthetic outcome was rated excellent by all patients.
Considering the limited clinical observation period, the performance of zirconia-based implant abutments for anterior crowns after 24 months is very promising. The temporary cementation seems to cause no increased risk of loss of retention. It therefore guarantees an undamaged removal of the suprastructures. When combined with zirconia-based crowns the tested zirconia abutments offer esthetic results with a very high level of patient satisfaction.
Objective:
This in-vitro study compared the fracture resistance of all-ceramic veneered cast alloy, laser-sintered alloy and computer-manufactured all-ceramic molar crowns with conventional cementation and adhesive bonding.

Method:
Single molar crowns were fabricated of a high gold alloy (Biopontstar, Bego) in A) cast technique (reference) or B) computer-designed laser-sintering technique and C) a computer-manufactured zirconia all-ceramic (Cercon/Ceram S, DeguDent). 8 crowns of each group were adhesively luted with Syntac Classic/Variolink2 (Ivoclar-Vivadent) and eight crowns with a Zn-phosphate cement (Harvard). The roots of the human molars were covered with a 1 mm thick layer of polyether to imitate the function of the periodontium. For simulating oral service, the crowns were thermally cycled and mechanically loaded (TMCL: 6,000 x 5°C/55°C, 1.2 x 10⁶ x 50N, 1.66 Hz) and then axially loaded to failure in a universal testing machine (Zwick 1446; v = 1 mm/min). Failure detection was set to 10 % of the maximum force. Statistical analysis was performed with the Mann-Whitney-U-test (P = 0.05).

Results:

Fracture resistance comparison:

<table>
<thead>
<tr>
<th></th>
<th>Cast alloy</th>
<th>Sintered alloy</th>
<th>Zirconia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>adhesive</td>
<td>conv.</td>
<td>adhesive</td>
</tr>
<tr>
<td>Median</td>
<td>1471</td>
<td>1221</td>
<td>1823</td>
</tr>
<tr>
<td>25 % Percentile</td>
<td>1141</td>
<td>1183</td>
<td>1410</td>
</tr>
<tr>
<td>75 % Percentile</td>
<td>1872</td>
<td>1515</td>
<td>2050</td>
</tr>
</tbody>
</table>

Typical failure of the veneering ceramic material after fracture load testing for an all-ceramic and a metal-ceramic crown.
Conclusions:

Zirconia restorations showed highest fracture resistance. The sintered alloy crowns provided a higher fracture force than the cast alloy. The type of cementation had no significant influence on the fracture results.

CAM zirconia and CAD laser-sintering – independent on the type of cementation – showed a fracture resistance after artificial aging which is expected to withstand the loading in posterior areas.

Fracture strength of the metal-ceramic and all-ceramic crowns

The box contains 50% of the data; it is limited on top and below by the 25% quantile. The median (50% of the measurements are above resp. below this value) is shown as a crossbar.
Objective: If an adhesive bond between zirconia and a resin is necessary, conventional methods failed which were developed for feldspatic or glass ceramics. It was the aim of this study to investigate the shear bond strength (SBS) of the zirconia/resin cement interface using different bonding concepts.

Method: Coplanar specimens of zirconia (Cercon, DeguDent) were bonded to CoCr cylinders (5 mm diameter, h = 3 mm) on restricted areas of 5 mm diameter using resin cements. The zirconia and CoCr bonding areas were sandblasted using 110 µm Al₂O₃ (2.8 bar, 10 s). Alloy Primer (Kuraray) was applied on all CoCr bonding surfaces. The resin cements were used according to the manufacture recommendations with or without priming of the zirconia surface: Enacem (GDF): Tender Bond, Tender paste, Maxcem (Kerr): no primer, Panavia F 2.0 (Kuraray): no primer, Rely X Unicem (3M Espe): no primer, Rely X Unicem: Rocatec silicoating. All cements were dark cured at 37 °C. The SBS was determined after 24 h water storage and after 12,000 thermal cycles (5 °C/55 °C, 17d). Analysis of the fracture types were carried out (cohesive, adhesive). The groups consisted of 8 specimens each. Statistics: Mean, std. dev., ANOVA.

Fabrication of specimens for testing the shear bond strength
Conclusions:

Results:

<table>
<thead>
<tr>
<th>SBS [MPa]</th>
<th>Enacem Tender Bond</th>
<th>Maxcem</th>
<th>Panavia</th>
<th>Rely X Unicem</th>
<th>Rely X Unicem Rocatec</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 h</td>
<td>20.1 ± 3</td>
<td>20.9 ± 5</td>
<td>23.5 ± 3</td>
<td>21.7 ± 4</td>
<td>27.8 ± 4</td>
</tr>
<tr>
<td>Thermal cycl.</td>
<td>18.7 ± 5</td>
<td>27.2 ± 6</td>
<td>19.9 ± 5</td>
<td>26.7 ± 5</td>
<td>26.9 ± 4</td>
</tr>
</tbody>
</table>

The SBS did not differ statistically after 24 h or thermal cycling. The failure occurred for Enacem, Maxcem or Panavia on the ceramic side. The CoCr bonding areas were all covered with resin cement. Only specimens bonded with Rely X Unicem and/or Rocatec showed cohesive fractures.

All investigated resin cements have the potential to achieve successfully an adhesive bond to zirconia all-ceramics.
Objective:
The aim of this prospective clinical trial was to examine the clinical behaviour of metal-free fixed partial dentures (FPDs) made out of zirconia frameworks that were veneered by a new ceramic overpressing technique.

Materials and Method:
A total of 21 three-unit FPDs replacing either a premolar or a molar were included. The preparation was done according to the manufacturer’s instructions. After impression taking with polyether material the restoration was manufactured on stone dies using Cercon smart ceramics (DeguDent, Hanau/Germany) zirconia frameworks and veneered with a new overpressing technique instead of the traditional layering technique. The restorations were tried in, occlusion, approximal points and color were checked and color corrections and individualizations were done. The FPDs were fixed by glasionomer cement. After 14 days and 12 months the restorations were again examined clinically. The patients’ and dentists’ satisfaction concerning function and esthetics was measured (Visual Analog Scale [VAS]: 10 is best, 0 is weakest).

Results:
After one year no fractures or complications have occurred, so that the Kaplan-Maier survival analysis revealed a probability of survival of 100%. Plaque and bleeding parameters haven’t changed significantly after treatment. Patients rated the esthetics with an average of 9.52 (SD 0.873) while dentists rated an average of 7.39 (SD 1.91) showing a significant difference between both groups (p = 0.001, Wilcoxon-test). Patients evaluated function of their FPDs 9.10 (SD 2.02) while dentists meant 8.90 (SD 2.01).
Conclusions:

Within the limitations of the relatively short time under observation posterior overpressed zirconia framework FPDs can be recommended so far. The advantages are perfect marginal fit and high esthetics having a circular ceramic shoulder. Patients are satisfied with functional and esthetic performance. The clinical trial will be continued in the future and conclusions about the longtime behaviour will be drawn.

Evaluation of the inserted PTC restorations (Cercon base/Cercon ceram press) by dentist and patient on a visual analog scale (VAS)

![Graph showing VAS scale evaluations](image-url)
Effect of Thermocycling on Bond Strength of Luting Cements to Zirconia Ceramic

Lüthy H., Loeffel O., Hammerle C.H.F.
Zurich, Switzerland (2006)

The objective of this study was to evaluate the shear bond strength of different cements to densely sintered zirconia ceramic after aging by thermocycling.

The following luting cements for bonding ZrO₂-TZP (tetragonal zirconia polycrystals) were used in this study: Ketac-Cem, Nexus, Rely X Unicem, Superbond C & B, Panavia F, and Panavia 21. Groups of 30 test specimens were prepared by bonding stainless steel cylinders tribochemically silica-coated with the Rocatec system to sandblasted ZrO₂-TZP ceramic disks (Cercon smart ceramics). Prior to testing, all bonded specimens were stored in distilled water (37 °C) for 48 h and half of them (n = 15) were additionally aged by thermocycling (10,000 times).

![Graph showing shear bond strength of various cements on densely sintered zirconium oxide after thermocycling.]

Shear bond strength of various cements on densely sintered zirconium oxide after thermocycling:
- KC: Ketac-CEM
- N: Nexus
- N+Rocatec: Nexus+Rocatec
- Unicem: Rely X Unicem
- Superbond: Superbond C & B
- Pan F: Panavia F
- Pan 21: Panavia 21
None of the fractures occurred at the interface of the metallic rods. The assemblies failed either at the interface between the ceramic surface and the cements or within the cements. Thermocycling affected the bond strength of all luting cements studied except for both Panavia materials and Rely X Unicem.

Within the limits of this in-vitro study the results showed that – after thermocycling – bond strengths for Ketac-Cem and Nexus were quite low. Nexus in combination with tribochemical silica-coating of ceramic surface produced a higher bond strength. The four adhesive resin cements (Rely X Unicem, Superbond C & B, Panavia F and Panavia 21) gave superior results. The strongest bond to zirconia was obtained with Panavia 21.
Clinical Performance of All-Ceramic Cantilever Bridges: 2-Year Results

Rinke S., Hanau, Germany (2006)

The clinical performance of all-ceramic cantilever bridges made of zirconium oxide was evaluated.

Between June 2002 and April 2004, 21 patients were restored with 26 all-ceramic cantilever FPDs made of yttria-stabilized zirconia (Y-TZP) in a private practice. The frameworks were produced with a CAM system (Cercon, DeguDent, Hanau/Germany). The restorations were cemented conventionally after 2 weeks of temporary insertion. The evaluation parameters were determined according to modified Ryge criteria: loss of retention, fracture of the framework, chipping of the veneering ceramics, color match, marginal integrity, and post-operative sensitivity. The degree of masticatory rehabilitation and the esthetic outcome were rated by the patients.

After a mean observation period of 629 days, neither a loss of retention nor a fracture of the framework or the veneering material were observed (success rate according to in situ criteria: 100%). The color match was rated Alpha for 85% of the restorations (Bravo for 15%). The marginal integrity of 45 abutment teeth was rated Alpha after 12 months (Bravo for 7 abutment teeth). 19 patients considered the esthetic result excellent or very good. 18 patients considered the masticatory rehabilitation excellent or very good. One abutment tooth required endodontic treatment, the restoration remained in situ.
The initial clinical performance of all-ceramic cantilever FPDs does not indicate a material-induced increased failure risk. Prior to a general recommendation of all-ceramic cantilever FPDs, further long-term studies should be evaluated.

Conclusions:

Patient evaluation (n = 21)

<table>
<thead>
<tr>
<th></th>
<th>Esthetic quality</th>
<th>Masticatory rehabilitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Very good</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Good</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Satisfactory</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Sufficient</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bad</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

3-unit Cercon cantilever FPD (after 36 months in situ)
Objective:
The aim of this in-vitro study was to determine the fracture strength and marginal adaptation of all-ceramic three-unit fixed partial dentures (FPDs).

Method:
Human molars were inserted in PMMA resin to create a three-unit (10 mm) oral situation. The roots of the teeth were covered with an about 1 mm thick layer of poly-ether to simulate the periodontium. 8 bridges of each series were made of the computer-aided manufactured zirconia (Cercon base/Cercon ceram kiss), an electro-layered chip-bridge system (Inceram Alumina-Wolceram) and a layering Al₂O₃ technique (Inceram Alumina, Vita; – control). All FPDs were fixed with an adhesive bonding system (Syntac classic/Variolink 2; Ivoclar-Vivadent). After thermal cycling and mechanical loading (TCML; 6,000 thermal cycles [5°C/55°C] and 1.2 x 10⁶ mastication cycles [50N]) fracture strength (UTM 1446; Zwick; v = 1 mm/min) was determined. Failure detection was set to 10% of the maximum force. Marginal adaptation was evaluated at both transitions cement-tooth (CT) and cement-FPD (CF) using scanning electron microscopy (Stereoscan 240, Cambridge Instr., GB) before and after TCML. The criterion “perfect margin” was ranked as a smooth transition without interruptions of continuity. Statistical analysis was performed with the Mann-Whitney U-test (p = 0.05).

Results:

<table>
<thead>
<tr>
<th>Fracture force [N]</th>
<th>Cercon</th>
<th>Wolceram</th>
<th>Inceram (control)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(25% - /75% - Percentil)</td>
<td>(1224/1428)</td>
<td>(487/735)</td>
<td>(315/673)</td>
</tr>
<tr>
<td>Median</td>
<td>1331</td>
<td>575</td>
<td>334</td>
</tr>
<tr>
<td>Marginal adapation [%]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT: before TCML</td>
<td>95.5 (91.5/99.0)</td>
<td>98.7 (96.8/99.3)</td>
<td>91.3 (83.9/93.3)</td>
</tr>
<tr>
<td>after TCML</td>
<td>98.0 (95.5/98.8)</td>
<td>98.6 (96.8/99.6)</td>
<td>86.9 (76.0/96.9)</td>
</tr>
<tr>
<td>CF: before TCML</td>
<td>97.0 (90.3/100.0)</td>
<td>98.4 (93.9/99.4)</td>
<td>90.1 (86.3/92.3)</td>
</tr>
<tr>
<td>after TCML</td>
<td>94.5 (87.8/98.0)</td>
<td>97.9 (95.2/99.2)</td>
<td>75.9 (69.1/89.8)</td>
</tr>
</tbody>
</table>
Electro-layered Al₂O₃ FPDs may only be used with restriction in posterior areas. The fracture forces of zirconia FPDs were at a level where clinical application seems promising.

**Conclusions:**

Zirconia CAM FPDs showed statistically significant higher fracture resistance than Al₂O₃ FPDs or electro-layered FPDs. Only the reference showed significant lower marginal adaptation.

Electro-layered Al₂O₃ FPDs may only be used with restriction in posterior areas. The fracture forces of zirconia FPDs were at a level where clinical application seems promising.
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www.cercon-smart-ceramics.com