CERCON® Zirconia

Conservative Options in Metal-Free Restorative Dentistry

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Cercon® Zirconia: Conservative Options in Metal-Free Dentistry

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Introduction

The current focus of esthetic dentistry is on tooth-colored, metal-free restorations usable in both the anterior and the posterior regions. With the introduction of Cercon transformation-toughened zirconia restorations, conservative dentistry has a new, esthetic metal-free option even for long-span restorations.

Since their introduction in 2002, Cercon zirconia restorations continue to be the clinician's choice for demanding situations where reliable, metal-free restorations are called for. In addition, research into performance aspects demonstrates that the promise of reliability of these restorations offer continues to be verified, both by clinical and by in-vitro studies. Most interestingly, we now have research that demonstrates that Cercon restorations perform as well as porcelain fuse-to-metal (PFM) restorations in the long term.

Framework Material	Cercon® Zirconia (ZrO_2, $Y2O_3$ 5%, Hf_2O_3 < 2%, Other oxides < 1%)
Composition	Yttria-stabilized tetragonal zirconia
Framework shades	• Neutral white • Shaded blanks
System Category	Computer Aided Milling (CAM) system, CAD (Computer Aided Design) option.
Indications (Anterior and Posterior regions)	• Crowns • Bridges up to 38mm, two abutments • Bridges to 47mm, multiple abutments • Telescope primary crowns • Inlay bridges (3 units)
Contraindicated	• In bruxism and parafunctional cases. • Maryland and Cantilever bridges are not currently indicated.
Veneering	Ceramco® PFZ porcelain, Cercon® Ceram KISS, Sakura® Interaction, Pressable options.
Cementation	Conventional cementation Adhesive bonding

System Overview

Reliable, biocompatible, esthetic, metal-free restorations for multiple-unit bridges have been the focus of dental materials research for the last decade[1]. Several materials have aimed to provide a solution to this need and have fallen consistently short of clinician and patient expectations[2-6] due to their low strengths and toughness. The Cercon system offers a comprehensive solution to this need. This innovative system takes advantage of the exceptional strength, toughness, reliability, and biocompatibility of translucent ceramic zirconia (zirconium oxide, ZrO_2), and combines this with the accuracy, control and advanced materials capability of an innovative computer-aided manufacturing (CAM) process. Cercon restorations (Table 1) can be placed with both conventional cementation and adhesive bonding techniques.

Cercon allows dental professionals to bring their wealth of clinical and lab experience to bear, to create a restoration that is best suited to a patient's needs. The Cercon system has been indicated for all single units. Two-abutment bridges with a maximum mesial-distal span of 38mm, and longer bridges up to 47mm with multiple abutments are also indicated, offering the clinician an excellent range of usage in the anterior and posterior regions (Table 1).

Table 1: The Cercon System has an Excellent Usage Range.

Recommended Usage	Illustration
Single units (anterior and posterior)	
Anterior Two-Abutment Bridges up to 38mm span, multiple pontics- (Multiple Abutment bridges up to 47mm span allowed)	
Posterior Two-Abutment Bridges up to 38mm span, multiple pontics- (Multiple Abutment bridges up to 47mm span allowed)	
Inlay bridges, 3 unit span	

Inlay bridges have recently been recommended, which allows a further extension of the application range of the system. Cantilevered and Maryland bridges are not currently recommended for this system, but are under clinical observation.

Zirconia: The Foundation of the System's Success

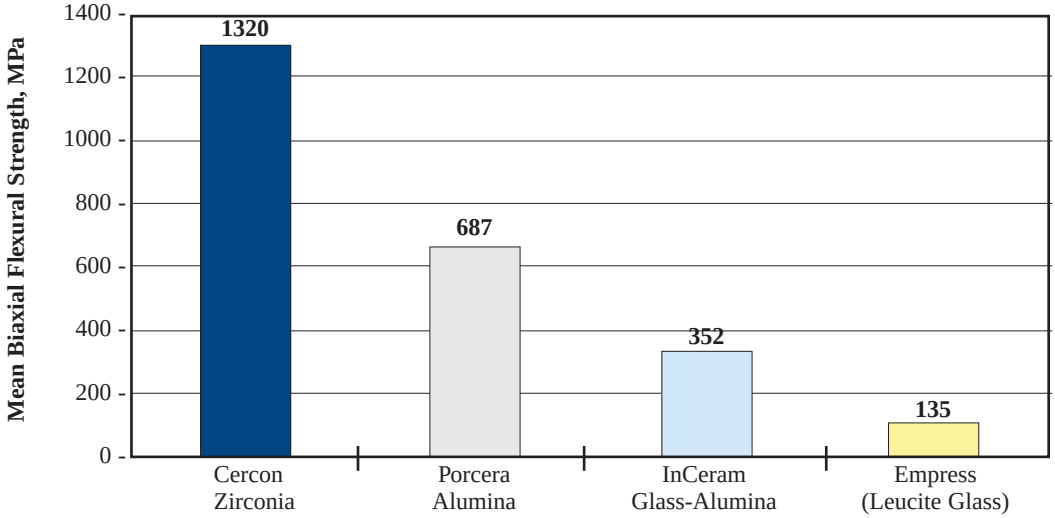
Zirconia (zirconium oxide, ZrO_2) is a highly stable oxide ceramic, typically used in industrial applications requiring high strength, resistance to chemicals, and stability (Table 2). Zirconia has served as a biomaterial for more than thirty years[7,8]. It is currently the material of choice for use in total hip replacements. Zirconia has a unique combination of excellent physical, mechanical and chemical properties that make it an ideal biomaterial.

Table 2: Zirconia Physical Properties

Density	6.1 g/cc
Vickers Hardness	1,200 VHN
Flexural Strength	> 1,300 MPa
MOE	210 GPa
Fracture Toughness	K_{IC}= 9 MPa.m $^{0.5}$
Corrosion Resistance	< 0.1 microgram/gram

The oral environment is unique in that it features low-level repetitive stresses and moisture. In such an environment, high strength is important; but strength alone is not sufficient to create a viable restoration. The resistance of a material to failure through the growth of small cracks- its toughness- is the best predictor of clinical success in a dental material. This is especially important in the molar region, where the highest stresses are observed. Microscopically small cracks started by chewing stresses, typically in the cemented side of a restoration, can initiate brittle failure in ceramics[9]. Zirconia's fracture toughness and flexural strength are significantly higher than that of alumina or any other esthetic ceramic (Fig. 1).

Figure 1: Cercon Zirconia' superior strength and toughness allow more uses than weaker ceramics.



Erdelt et al., Quintessenz Zahntech, 30 (9), p942, 2004; Wagner et al., Prosthet Dent, 76, p140, 1996

Zirconia is also unique among dental ceramics in that it exhibits a physical property called transformation toughening[10]. Through the appropriate use of additives, such as yttrium oxide, zirconia articles can be made in the tetragonal crystal structure at room temperature. When an external energy source- such as the stress at a crack tip- is applied to the material, it goes through an instantaneous phase transformation to a monoclinic crystal structure. The monoclinic form of crystal is about 4% larger in volume than the tetragonal form. At the microscopic crack tip, this expansion upon transformation acts to clamp the crack shut, thus resisting crack propagation (Fig. 2).

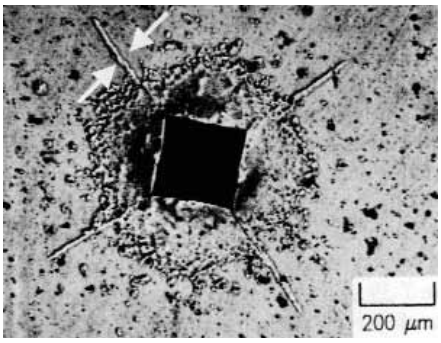


Fig. 2: Transformation toughening arrests crack growth in Cercon Zirconia

This process of actively resisting crack growth is of great importance in fatigue situations, such as caused by chewing forces on a restoration. No other dental ceramic exhibits this phenomenon. In practical terms, this combination of outstanding strength, toughness and transformation toughening properties makes zirconia the superior choice for a reliable restoration in the molar region.

Clinical Procedure Recommendations

The Cercon system directly integrates with today's state of the art in dental technology and practices. Some competitive computerized systems require a significant learning curve before the technology can be employed. The system features efficient capabilities that integrate the professional skills and judgment of the clinical practitioner and lab professional. The clinical and lab process flow is outlined below.

Shade Selection

Cercon restorations can be placed as an alternative to most cases where a PFM (porcelain fused-to-metal) would be diagnosed. Cercon restorations can be created in shades keyed to the Vita Lumin Classic shade guide (shades A1-D4). Bleached restorations keyed to the *illuminé*™ shade guide offer the esthetic practitioner eight more shade choices (*i*1-*i*8) brighter and lighter than A1 or B1 (Fig.3).

Fig. 3: illuminé shade guide with bleached shades.

Preparation Guidelines – Conventional Restorations

Preparation guidelines for Cercon restorations are conservative, and familiar to most practitioners placing metal-free restorations (Fig. 4). We recommend a prep angle of 6-8°, and a flat occlusal opening angle (120-140°). Sharp line angles and undercuts are to be avoided (Table 3). However, Cercon certified laboratories can smooth out sharp line angles and block out undercuts before waxing restoration substructures.

Table 3: Preparation Guidelines for Cercon Restoration

Restoration	Margin Type	Axial Reduction	Occlusal Reduction	Coping Thickness
Anterior Crowns	Shoulder, Chamfer	≥ 0.8 mm	≥ 1.5 mm	0.3mm / 0.2mm margin
Posterior Crowns	Shoulder, Chamfer	≥ 1.0 mm	≥ 1.5 mm	0.4mm / 0.2mm margin
Bridges	Shoulder, Chamfer	≥ 1.0 mm	≥ 1.5 mm	0.4mm / 0.2mm margin

Fig. 4: Representative anterior and posterior preparations for Cercon Restorations

Preparation Guidelines – Inlay Bridges

Inlay bridges are a conservative restorative option, especially when preservation of natural tooth structure is a concern[11-14]. Preparing a restorative site for a Cercon inlay bridge is relatively straightforward, and is comparable to preparing for other inlay restorations (Fig. 5). Inlay bridges are typically single-span (three-unit) constructions and are used for replacing a missing second premolar. Inlay bridges to replace first molars should be considered only in very carefully selected cases, if the occlusal relationships are favorable, and if the width of the pontic is 10mm or less.

Fig 5: Preparation and Post-Operative View of Cercon Inlay Bridge.

The following guidelines may be kept in mind when preparing the inlay-retained bridge.

- Full Coverage Abutment:
  - The full-coverage abutment is prepared conventionally, with ≥1mm axial and ≥1.5mm occlusal reduction, and smooth line angles.
  - The full coverage abutment may be conventionally cemented or adhesively bonded.
- Inlay Abutment:
  - Care must therefore be taken to ensure sufficient width of the proximal boxes (4mm) and appropriate height (4–5mm).
  - The connector area should not be less than 9 sq. mm.
  - A preparation angle divergence of 2° to 3° is recommended.
  - The preparation should have smooth rounded line angles, and be free of retentive elements.
  - The angle between the facial and lingual aspects of the proximal box and the tooth's external surface should be between 70° and 90°.
  - Vestibular or lingual extensions, as well as beveling of cavosurface margins are not recommended.

Cercon offers several advantages over other all-ceramic alternatives. Because of the strength and reliability of the core material, zirconia, a coping wall thickness of 0.3mm is sufficient in most cases. The margin area in the anterior may be finished down to 0.2mm for esthetic purposes.

In the area of connector sizes, Cercon offers an unparalleled esthetic advantage. Connector sizes of 9-11mm^2 are sufficient to create esthetic restorations, with harmonious dimension. These dimensions are much more lifelike compared to the 20mm^2 (4x5mm) connector dimensions demanded by lithium disilicate based restorations, such as IPS Eris.

Taking Impressions

We recommend the double-cord technique for impression taking with Cercon restorations. Several cord systems such as UltraPak (Coltene), and ExpaSyl (3M/ESPE) have been recommended by Cercon practitioners. Impressions can be taken with a variety of materials such as hydrocolloids, polyethers (PolyJel®, Dentsply Caulk), or polyvinyl siloxanes (Reprosil®, Dentsply Caulk).

We recommend the new Aquasil Ultra Smart Wetting® impression material from Dentsply Caulk, as it offers a combination of excellent impression accuracy, along with high tear strength that enables labs to process restorations confidently. We find that the Rigid, Heavy and LV viscosities are routinely used by most practitioners. In return, the practitioner and the patient achieve the fit and the performance they expect from a restoration. The mint-flavored material also enhances patient's comfort and relaxation.

Temporization

We recommend Integrity™ temporary crown and bridge material (Dentsply Caulk) for temporization. In placing temporary crowns, care must be taken to avoid eugenol-based materials, if the practitioner plans to bond the final restorations in place.

Lab Process

The impression of the prepared restoration area is sent to a trained Cercon dental laboratory. The lab duplicates the preparation, and designs a restoration in wax. The wax model is placed in the Cercon® Brain and scanned by a precision confocal laser.

The pattern is then machined out of a Cercon® Base blank of presintered zirconia in an enlarged size. The enlargement factor compensates for the sintering shrinkage (~18% linear), and is contained in a barcode on each blank. The milled coping or framework is sintered in the Cercon® Heat furnace at 1350°C for six hours. After sintering, the dimensions of the strong, tough Cercon framework match the dimensions of the wax pattern (Fig. 6). An entire day's output from the Cercon Brain (30 units+) may be sintered overnight.

Fig. 6: : Wax Model, Cercon milling in the Brain, and framework being sintered.

Restoration Placement - Esthetics

Excellent esthetic results may be achieved for Cercon restorations veneered with low-fusing, leucite-free Ceramco PFZ veneering porcelains. Cercon restorations are translucent, since they are composed of dense ceramics with a low (0.3-0.4mm) coping thickness (Fig. 7).

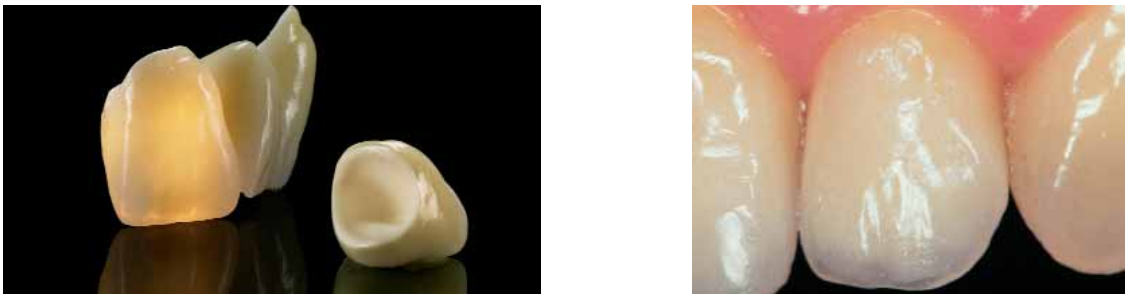


Fig. 7: Transilluminated Cercon restoration, with anterior esthetic crown results.

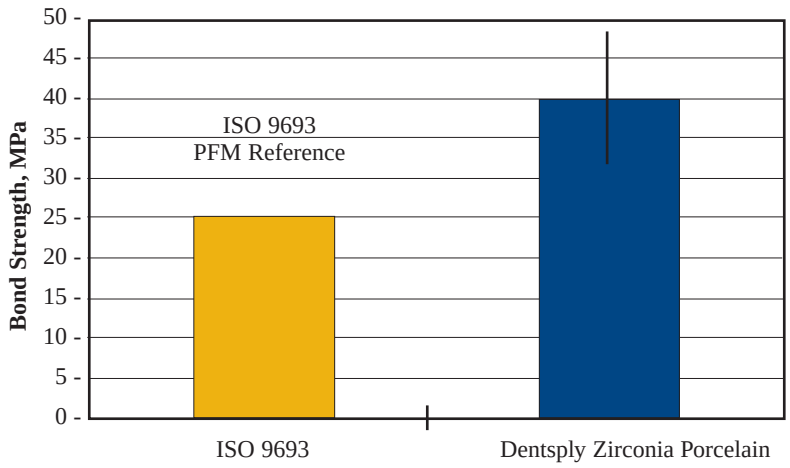
Two shades of Cercon framework material, in neutral white and a natural tooth colored shade, are available for an esthetic range (Fig. 8).

Fig. 8: Neutral and Shaded Cercon base materials can be porcelain veneered for esthetics.

The sintered Cercon framework is veneered with the esthetic, low-fusing Ceramco PFZ (Dentsply Ceramco), Sakura Interaction (Elephant Dental), or Cercon Ceram KISS (DeguDent) veneering porcelains. These veneering porcelains are all leucite-free synthetic porcelains that are feldspathic in nature, and have been specially adapted to the thermal expansion behavior of zirconia (CTE ~ 10.5ppm/K, 500°C). This adaptation has been verified in long-term in-vitro oral stressing and thermocycling tests, as well as in clinical and laboratory practice.

The bonding strength of veneering porcelain to Cercon zirconia has been uniquely tested in comparison with PFM restorations[15]. The bond strength significantly exceeds the minimum limit of 25MPa when tested according to the ISO 9693 international standard for metal-ceramic bond strength testing (Fig. 9)

Fig. 9: Dentsply zirconia porcelains have excellent adhesion to Cercon



The cementation surfaces of the restorations are lightly sandblasted with alumina by the lab, and cleaned. The restoration may now be placed using conventional luting or adhesive bonding.

Restoration Placement – Conventional Luting

Cercon restorations have a clinical history of success, with both bonding and conventional cementation. This offers the practitioner a wide variety of choices in placing the final restoration. Several clinical trials attest to the excellent retention of Cercon restorations with a variety of cementation options (Table 4).

Table 4: Clinical Research Summary for Cercon Cementation

Luting Method	Site, PI	Units	Start Date	Comments
Bonding (Panavia 21, J. Morita)	Univ. of Zurich, Prof. P. Schärer	59	April 1998	Successful bonding to date in all types of cementation.
Cementation, Glass Ionomer (Ketac Micro, 3M Espe)	DeguDent, Dr. S.Rinke	25	June 2000	
Cementation, Zinc Phosphate (Harvard Cem, Harvard)	Univ. of Göttingen, Prof. A. Hüls	52	Sept. 2000	
Cementation, RRGI, (Dyract® Cem Plus, Dentsply)	Univ. of Maryland, Dr. D. Barnes	60	April 2003	

Excellent retention forces have been obtained in in-vitro studies, with a wide variety of luting materials. Cercon certified laboratories are trained to microetch the cementation surface of the restoration before it is delivered. Microetching with alumina roughens the surface, and enables cements to adhere strongly to zirconia through micromechanical retention (Fig. 10). The use of a bonding agent enhances the chemical bond, but only on the tooth side. As always, all recommendations of the bonding system must be followed. We recommend the use of Calibra® esthetic resin cement, with Prime and Bond® NT™ dual-cure bonding agent (Dentsply Caulk) for practitioners who prefer the stronger bonds and long-term clinical advantages offered by bonding (Fig. 11).

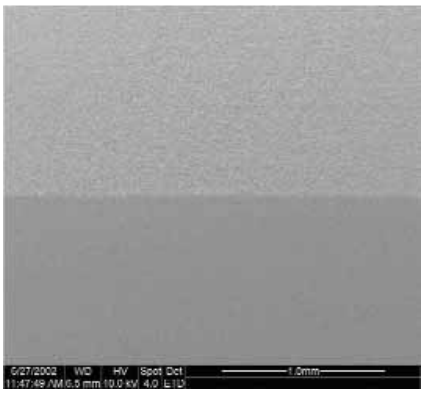
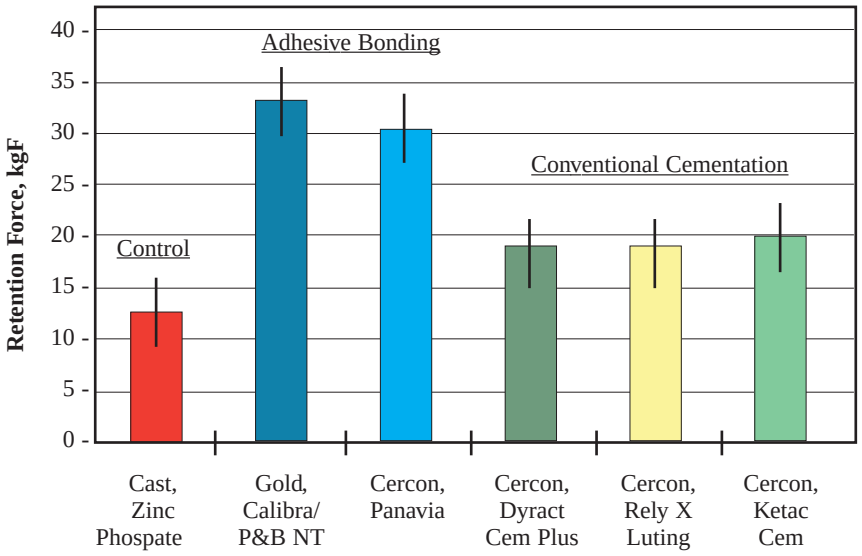


Fig. 10: Microetched retentive (above) and smooth, less retentive (below) surfaces of Cercon

Fig. 11: Retention Forces of Cercon with a variety of cements exceed the control requirements. (Data from Dr. C. Pameijer)

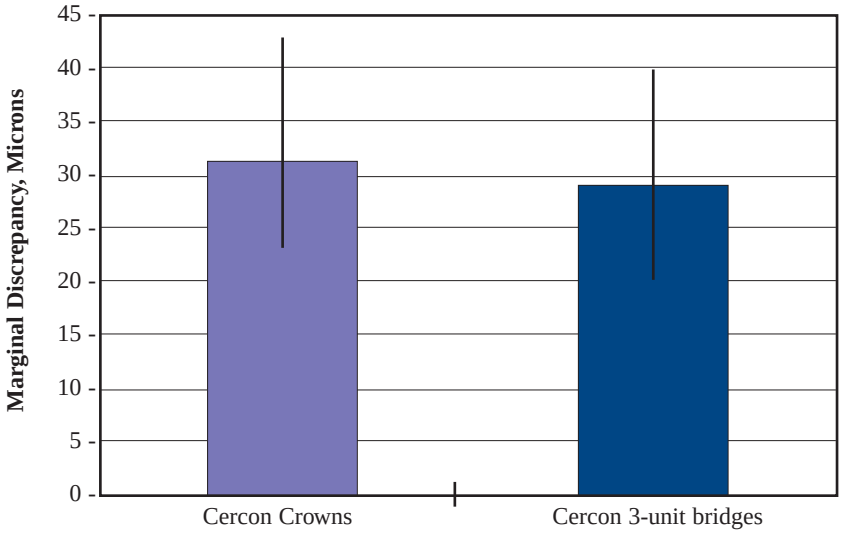


For Cercon inlay bridges, adhesive bonding of the inlay abutment is necessary, especially when porcelain margins are used. To condition the cement-bearing surfaces, the zirconia framework surfaces are air-abraded, and veneering ceramic surfaces are etched with hydrofluoric acid. The etched surfaces must be silanated. The adhesive used must be a self-curing or dual-curing cement such as Calibra® (Dentsply Caulk), with Prime and Bond® NT™ bonding agent. The full coverage abutment may be conventionally cemented.

Restoration Placement – Fit

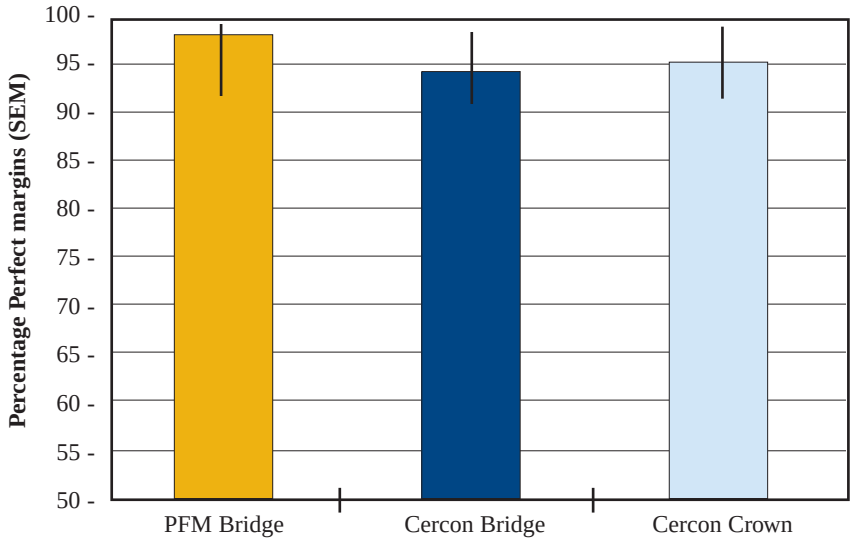
Because the fit of a Cercon restoration is controlled by the lab, it is possible to achieve optimal fits tailored to the dentist's preferences. Layers of die spacer are used to create fits ranging from exact to passive fits. Marginal gaps of 50 microns or better are consistently achievable. Marginal integrity has been evaluated to be of the order of 30 microns for crowns and bridges (Fig. 12)[16].

Fig. 12: Average marginal openings for Cercon restorations are in the 30 micron range



In the long term, marginal gaps of Cercon restorations do not degrade, even though ceramic margins are in use. An SEM (scanning electron microscope) evaluation of the margins of Cercon 3-unit bridges was completed by the University of Regensburg, with the understanding that long-term clinical performance is also dependent on marginal function, before and after thermal cycling and mechanical loading equivalent to 5 years of service. The marginal adaptation was rated in terms of percentage of perfect margins for 3-unit bridges and for single crowns[17] (Fig. 13).

Fig. 13: Cercon restorations display excellent fit after 5-year simulated service.



The investigators concluded that the materials showed comparable good marginal integrity. Combining the results from these two studies with clinical experience, we conclude that excellent marginal fit may be obtained with the Cercon system.

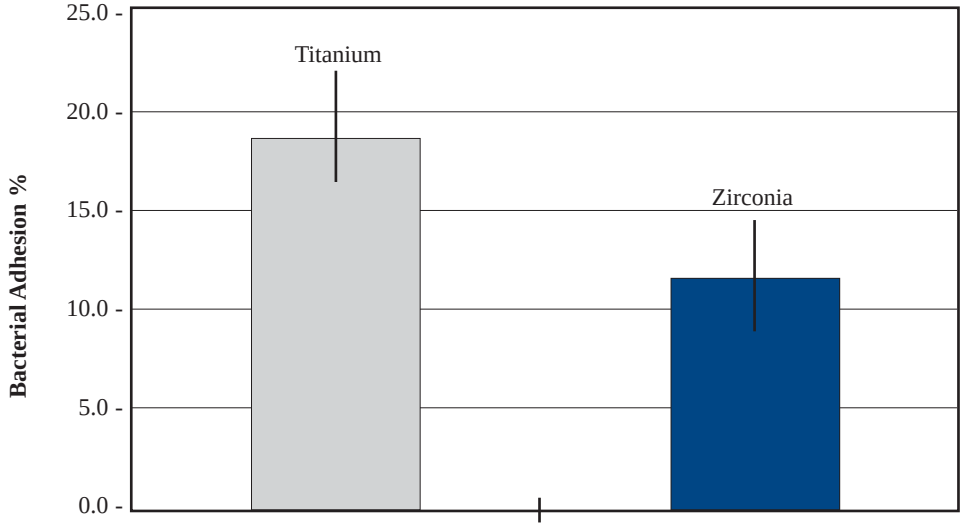
Post Placement Treatments

During and after placement, any adjustments to the zirconia sections of the restorations may be performed with water-cooled diamond tools. The porcelain sections of the restoration may be polished with conventional ceramic polishing systems (Fig. 14).

Fig. 14: Occlusal adjustments and polishing of Cercon restorations.

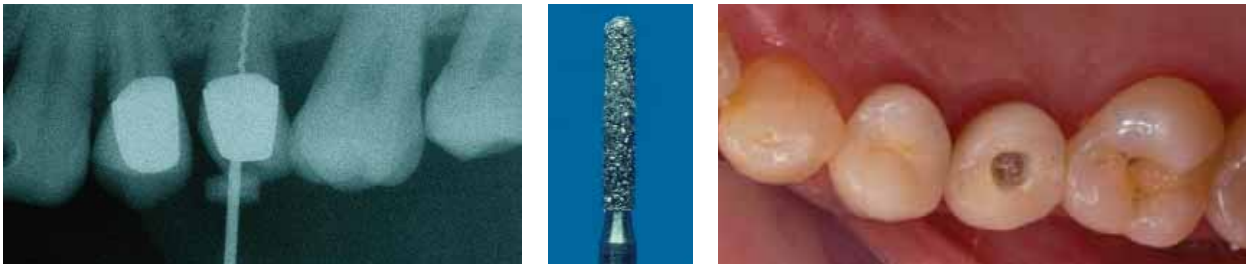
Several studies continue to demonstrate the clinical success of zirconia in dental applications, and the relatively rare need for post-placement therapeutic intervention[18-20]. Of particular interest to the dental community is a study that compared bacterial adhesion to Cercon zirconia and titanium[21]. A significantly lower level of bacterial adhesion was observed to Cercon (Fig. 15). This could have positive implications for the plaque resistance of Cercon restorations.

Fig.15: Oral bacterial adhesion to zirconia is significantly lower than titanium



Another special case of interest is endodontic intervention. Cercon restorations are radiopaque. If it becomes necessary, endodontic access can be easily established through a Cercon restoration. We recommend using a coarse (80-125 micron) grit diamond tool, and using a two step procedure. In the first step, a wider porcelain access cavity is established, followed by a zirconia access cavity with a narrower diameter (Fig. 16). After appropriate therapy, the occlusal surface may be restored with a composite material[22].

Fig. 16: Radiograph of Cercon restoration, coarse (100 micron) diamond tool, and endo access through Cercon

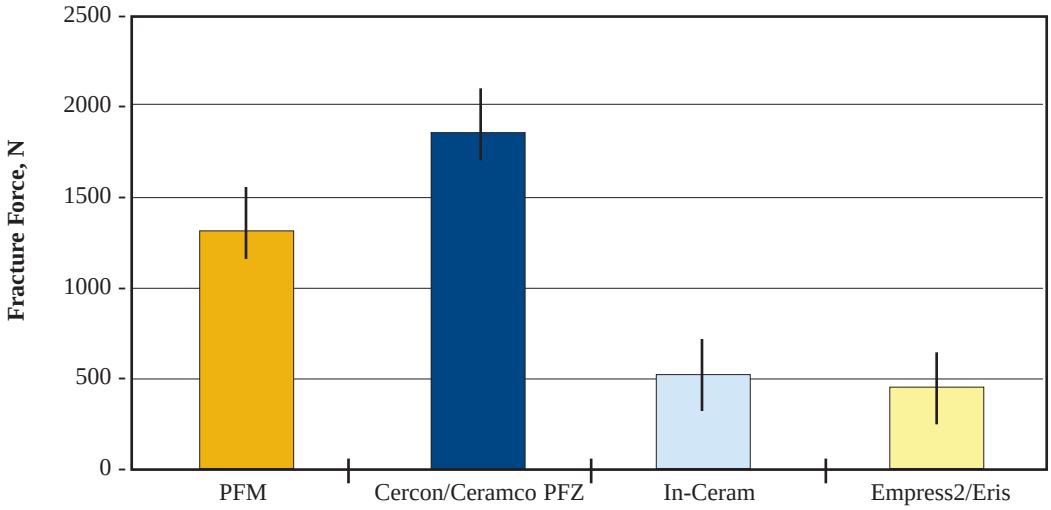


Performance compared to PFM Restorations

Probably the most exciting updates about Cercon's performance with Ceramco PFZ veneering porcelain comes out of long-term intraoral simulation studies at the University of Regensburg. The aim of this study was to compare the fracture resistance and marginal adaptation of Cercon restorations with that of conventional PFM restorations. Both types of restorations were anatomically contoured and veneered with recommended porcelains. Twenty four 3-unit bridges were fabricated of Cercon and control PFM bridges.

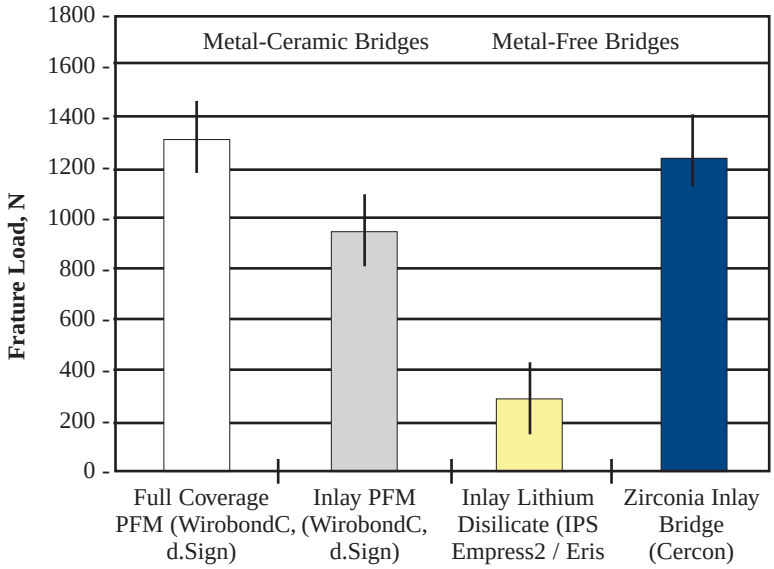
In order to simulate the oral environment accurately, the bridges were fabricated to fit extracted human molar teeth set in a polymethyl methacrylate resin base. The roots of the teeth were lined with a polyether layer simulating the periodontum. The bridges were adhesively bonded to these teeth, and fractured after thermal cycling and mechanical loading (6000 cycles, 5°-55°C in water and 1.2 million cycles of 50N loads), which is equivalent to five years of intraoral service. The fracture loads achieved by these bridges were then statistically compared (Fig. 17). The investigators concluded that Cercon and PFM restorations performed equivalently, after five years of simulated service life[23].

Fig. 17: Cercon 3-unit bridges perform as well as PFM after 5-year simulated service.



Performance against a PFM control has been verified for inlay-retained Cercon bridges, as well. A recent study compared the fracture resistance of posterior metal-ceramic and all-ceramic inlay-retained resin-bonded fixed partial dentures. Eight bridges each in four subgroups: full coverage PFM and inlay-retained PFM (Wirobond C nonprecious alloy, Wieland Dental) veneered with d.Sign (Ivoclar AG), inlay-retained lithium disilicate (IPS Empress 2, Ivoclar AG), and inlay-retained Cercon bridges were compared for fracture resistance[24]. PFM specimens were prepared with a 1.3mm circumferential, 90° flat shoulder with rounded line angles. Inlay-retained specimens were prepared with 2mm occlusal reduction but without bevels at the occlusal or gingival margins.

Fig. 18: Fracture comparisons of Cercon against PFM inlay bridges show superior performance.



The researchers concluded that inlay-retained Cercon bridges achieved the greatest fracture resistance among all inlay-retained restorations tested including PFMs (Fig. 18). The fracture resistance of the Cercon inlay bridges was statistically equivalent to that of full coverage PFM restorations.

Continuing Developments

As a comprehensive system, Cercon provides a platform for continuous developments. A few key enhancements that are currently in late-stage development are outlined here.

Cercon Link:

Cercon Link is an extracoronal connector (attachment) for the fabrication of stress-relieved bridges to restore jaws with divergent abutments. The attachment is to be placed between a terminal abutment and its immediately adjacent pontic. The Cercon Link shape was designed using advanced Finite Element Analysis methods. The result was a modeling aid made out of polysulphone, a resin material that can be milled precisely. With its precise tapered shape it can be scanned and milled accurately by the Cercon Brain. Cercon Link can be used to connect bridge segments with three pontics in the anterior region or two pontics in the posterior region. The total length of the bridge must not exceed the anatomical length of the zirconia blank (Cercon base 47). We are currently examining the efficacy of Cercon link for use as a connector in the fabrication of bridges in excess of 47 mm of anatomical length. At present, this use is not yet indicated.

Fig. 19: Cercon link waxed on to abutment, milled and sintered, and the secondary attachment

Pressable Veneering Material for Cercon:

Many clinicians have expressed an interest in having pressed ceramic shoulders available for Cercon restorations. A pressable veneering material for Cercon is available on the international market (Cercon Ceram Express, DeguDent) that is CTE matched to the Cercon base material and allows customization of the restoration using incisal cutback and staining techniques. An investment mould is made using a lost-wax technique, and the veneering ceramic is slowly injected at medium pressure (940°C, ~30 min, 5 bars) into the cavity. The material allows the fabrication of shrinkage-free pressable margins, with a homogeneous structure of the veneering material. Sharper preparation margins are reproduced with high fidelity, and occlusion can be checked on the articulator by the lab for customization.

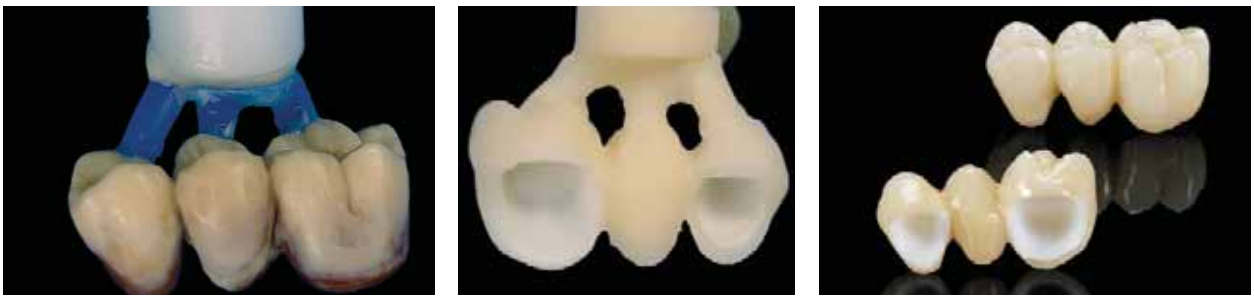


Fig. 20: Pressed ceramic wax-ups, pressing output and final restoration.

Cercon: A CAD Module:

A computer-aided design (CAD) module for Cercon is also in late-stage development. Capable of scanning model dies using the laser scanner in the Cercon brain, this module offers a cost-effective method to fabricate high-strength ceramic single units in a dental laboratory, without the use of outsourcing. The graphical user interface (GUI) is intuitive, and allows the fabrication of copings customized for cementation gaps, wall thicknesses, and occlusal geometry. Automatic margin detection allows the optimization of fit, to the clinician's and patient's benefit.

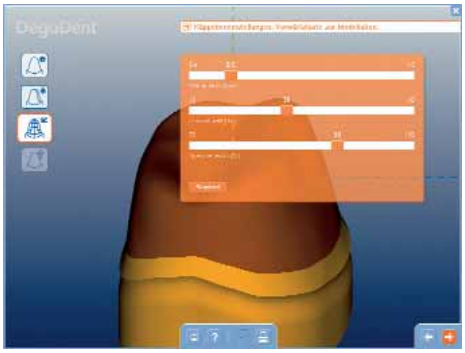


Fig. 21: Die in Scan Holder, and Cercon CAD Screen with customization options.

Cercon® Balance All-Ceramic Implant Abutments

The resolution of the Cercon system does not currently permit the custom milling of abutments, which requires micron-order accuracy. However, esthetic implant dentistry is possible using the Cercon® Balance abutment from the Ankylos (Dentsply Friadent) system. The abutment is uniquely configured so that a wax coping can be custom-adapted without rotation. The Ankylos system is designed to provide the implantologist and the restoring dentist a great level of flexibility in patient care for implant sites.

Fig. 22: Esthetic all-ceramic Anklyos Balance Implant Abutments

Summary

Cercon zirconia restorations are a proven metal-free esthetic restorative option, with a very wide indication range, including posterior long-span and inlay bridges. The clinical protocol for placing these restorations is similar to most esthetic restoration options, but offers restoration performance comparable to the clinical standard of porcelain fused-to-metal restorations. Ongoing research studies attest to the biocompatibility, laboratory and clinical viability and the excellent long-term performance of zirconia. In the light of new research, we can be confident that Cercon restorations can offer the convenience and the reliability of PFM, combined with all-ceramic esthetics. New developments such as semi-precision attachments, a pressable veneering system, and a CAD option will only increase the functionality and breadth of application of the system.

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The authors gratefully acknowledge the contributions of Drs. Gordon Christensen, Lou Graham, David Little, Cornelis Pameijer, and Sven Rinke to Cercon dentistry and to this article.

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