A New Metal-Free Alternative for Single- and Multiunit Restorations

Abstract: More than 40 years after their development, porcelain-fused-to-metal (PFM) restorations remain the clinical standard against which other esthetic dental materials are measured. One of the challenges of PFM restorations, as with many indirect restorations, is the task of making them appear lifelike when viewed adjacent to natural teeth. All-ceramic restorations have become a welcome addition to the restorative armamentarium because their lack of a metal substructure allows them to blend well with surrounding natural dentition. While all-ceramic materials were initially used to veneer teeth and improve esthetics, they began to be used for full-coverage crowns and, more recently, to replace missing teeth as well.

The search for a high-strength, esthetic, biocompatible, metal-free material that could be used for multiunit frameworks as well as single-unit restorations, has been the focus of many research-and-development efforts during the last decade. Several materials have attempted to meet these needs, yet have fallen short of clinicians’ expectations because of their low strengths and toughness. Figures 1 and 2 compare the flexural strengths and fracture toughness of some other all-ceramic materials to the recently introduced Cercon® Smart Ceramics™ system by DENTSPLY®/Ceramco® (data on file, DENTSPLY®/Ceramco). The fracture toughness and flexural strength of zirconia are significantly higher than that of alumina or any other currently available esthetic ceramic (Figures 3A and 3B). The Cercon® system offers a comprehensive solution to these needs by taking advantage of the strength, toughness, reliability, and biocompatibility of zirconium oxide, along with the accuracy and control of a computer-aided manufacturing (CAM) process. Currently, the Cercon® system is the only CAM commercially available in the US dental market that has the ability to mill a presintered zirconia block into a multiunit restoration.

Patient Selection

A metal-free bridge that can be used anywhere in the mouth is desirable for several different patient groups. The first group is patients who report allergies to metals on their medical history. This is usually reported as allergies to various base metals, such as those found in costume jewelry. The second group is an offshoot of the first group, and consists of patients who are metal-phobic. These patients often ask to have their silver amalgam fillings removed because of something they have heard or read. When these patients require an indirect restoration, they are usually adamant about receiving a tooth-colored restoration. The last group is comprised of patients with esthetic concerns. These patients tend to object to any metal-containing restorations, even if it is confined to a small area on a lingual surface. Even if a dentist were to design a PFM crown that had a 360-degree porcelain shoulder margin, these patients often will object if allowed to see the internal aspects of the restoration. For these different groups of patients, zirconia can be used as a metal substitute. Figure 4 shows a radiograph of a typical PFM bridge, while Figure 5 shows a radiograph of a Cercon® zirconia bridge. Note the density of the zirconia framework and

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Learning Objectives

After reading this article, the reader should be able to:

- list the patient groups that would benefit from the use of zirconia-based ceramic restorations.
- discuss transformational toughening, the unique physical property of zirconia.
- describe the indications and preparation guidelines for the Cercon® system.

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Figure 1—Flexural strength of zirconia.

Figure 2—Fracture toughness of zirconia.

how it is essentially indistinguishable from the metal framework of the PFM bridge.

Zirconia as a Biomaterial

Zirconia (zirconium oxide, ZrO₂) is a highly stable ceramic oxide typically used in industrial applications requiring high strength and stability that has a history as a biomaterial dating back to the 1970s. It is used in orthopedic implants and other non-dental applications extensively, and is currently the material of choice for use in total hip replacements. Hip replacements parallel dental applications in that they are both load-bearing situations with close proximity to vascular and osseous tissue. They also both involve articulated joints that experience wear.

Zirconia and Transformational Toughening

The oral environment is unique because it features low-level repetitive stresses in the presence of moisture. In an environment like this, high strength is important, but strength alone is not sufficient to create a long-term, stable restoration. This is especially true in the molar region where the highest stresses are observed. Microscopic cracks started by chewing stresses, typically in the cemented side of a restoration, can initiate brittle failure in ceramics. Zirconia is unique among dental ceramics in that it exhibits a physical property called transformational toughening (strengthening). Through the use of additives, such as yttrium oxide, zirconia can be made in the tetragonal crystal structure at room temperature. When an external energy source, such as the stress at the tip of a crack, is applied to the material, it goes through an instantaneous phase transformation to become a monoclinic crystal structure. This monoclinic form of zirconia crystal is about 4% larger in volume than the tetragonal form (data on file, DENTSPLY/Ceramco). At the microscopic tip of the crack, this expansion upon transformation acts to clamp the crack shut, thus resisting crack propagation (Figure 6). This process of actively resisting crack growth is of great importance in fatigue situations, such as those caused by chewing forces on a restoration.

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Strength Testing

The strength of Cercon® zirconia bridge frameworks was compared in an in vitro study in

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Figure 8 shows the results of a study conducted at the University of Regensburg, which evaluated retained strength after fatigue by subjecting the bridges to 5 years of simulated oral stress and thermocycling. The results illustrate the long-term reliability of Cercon® zirconia compared to the other materials. The weakest Cercon® bridges in this study tested stronger than the strongest In-Ceram® and IPS Empress® 2 bridges.

**Clinical Studies**

In vivo studies were begun at the University of Zurich 3 years before the release of Cercon® to ensure the clinical reliability and long-term viability of Cercon® zirconia restorations. In the 1-year recall published during this study, 23 three-unit bridges and a four-unit bridge were placed and observed. Nineteen of these bridges had a molar tooth as an abutment, while 11 of them had a molar pontic. These bridges had maximum connector dimensions of 7 mm² to 11 mm², comparable to the connector dimensions of PFM frameworks. These small connector sizes make it easier for the technician to achieve ideal esthetics, especially on anterior bridges. All of the bridges were intact at the 1-year recall and a high level of patient satisfaction was reported. As of the 3-year recall mark in October 2001, no damage was recorded in any of the bridges placed for this study.

**Laboratory Procedure**

After receiving the impression from the dentist, the laboratory pours and articulates the models in the usual fashion. After blocking out any undercuts, the crown or bridge framework is
waxed to ideal dimensions (Figure 9). By using a traditional wax-up, the Cercon® system allows technicians to impart their technical expertise when designing connector size, shape, and placement. The typical coping thickness is 0.4 mm, giving the technician the maximum amount of space to develop the esthetics of the restoration. The wax-up is then attached to a special holding appliance via wax rods and inserted into the Cercon® brain unit. A zirconia blank is inserted into the other side of the Cercon® brain unit (Figure 10). Each individual blank is bar-coded to give the Cercon® brain unit specific information regarding the enlargement factor and other milling parameters. Because zirconia can exhibit shrink factors near 30% during the sintering process, the Cercon® brain unit accounts for this shrinkage during the milling process.

A fully automatic procedure then begins in which the wax-up is scanned by a laser, and the zirconia blank undergoes first a coarse and then a fine milling process (Figure 11). The entire procedure takes about 35 minutes for a single-unit crown and approximately 80 minutes for a four-unit bridge. After milling, the crown or bridge framework is separated from its frame and is ready for sintering in the Cercon® heat unit (Figure 12). Sintering takes place at 1350°C in a 6-hour cycle. The sintered framework is then placed back on the model to verify fit (Figure 13). The technician can make slight modifications to the external dimensions of the presintered framework with a rotary instrument. Pressure-indicating sprays, such as Occlude®, can be used if necessary to verify complete seating of the framework. The Cercon® Ceram-S veneering ceramic can then be applied per the manufacturer's directions in the desired shade combination (Figure 14).

Zirconia is unique among dental ceramics in that it exhibits a physical property called transformational toughening (strengthening).

Indications and Preparation Guidelines

Cercon® is indicated for the fabrication of anterior and posterior single-unit crowns, and bridges with a maximum span of 38 mm, which corresponds to the length of the longest Cercon® blank. Typically, this length can accommodate nearly all four-unit molar bridges as well as anterior bridges less than 38 mm in length.

The Cercon® preparation is accomplished in accordance with the general principles common to most all-ceramic systems. Standard all-ceramic modified shoulder margins (accomplished with burs containing the KR designation) or chamfer margins 1 mm deep are both

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acceptable. Proximal reduction of 1.5 mm is ideal, as is 1.5 mm to 2 mm of occlusal reduction. The taper of the final preparation should be 6 to 8 degrees and undercuts are undesirable, although these can be addressed in the laboratory if necessary. One difference between the Cercon® preparation and many other preparations is the preferred design of the preparation’s occlusal table. Typically, the occlusal table of a preparation is designed to mimic the preopera-

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be placed with either conventional cementation or adhesive bonding techniques. The manufacturer suggests no special conditioning of the framework in either case.

Clinical Cases
Case 1
Case 1 involved a 48-year-old man whose lower first and second molars were missing (Figure 15). The remaining third molar exhibited good periodontal health with no mesial tilting, which commonly occurs with missing posterior teeth. It was planned that the Cercon® bridge would extend from the lower second
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Case 2

Figures 19 and 20 show the preoperative smile of a 57-year-old woman who presented with multiple broken veneers. The patient also reported thermal sensitivity on two of her teeth. The veneers on teeth Nos. 7 and 8 had broken at the incisal edge, and tooth No. 9 had a vertical fracture in the veneer from the incisal edge to the gumline. To provide the patient with stronger restorations that could be cemented, it was decided that Cercon® crowns from teeth Nos. 5 through 12 would be used. The patient declined to have anterior crown lengthening done on teeth Nos. 7 through 10, which would have properly aligned the gingival crests and zeniths. After
removing the existing crowns, standard PFM preparation dimensions and techniques were followed. Figure 21 shows the facial view of the cemented Cercon® restorations. Figures 22 and 23 show the lateral views of the new smile. The patient has reported that the previous sensitivity has disappeared. Before cementation, two coats of Hemaseal & Cide Desensitizer™ were placed on the preparations and evaporated with air. The crowns were then cemented with RelyX™ Luting Cement.

The Cercon® framework is strong enough to allow the clinician to adjust the occlusion before bonding or cementation.

**Case 3**

Case 3 demonstrates an experimental design, the fabrication of a maxillary anterior three-unit bridge in which the two central incisors are used as splinted abutments to support the adjacent lateral incisor. In Figure 24, the wax-up is on the master model with the interproximal connector size recommended by the manufacturer. In Figure 25, the milled Cercon® framework is on the master model. Figure 26 shows the final bridge on a duplicate model poured with a soft tissue index to help the laboratory technician fabricate the gingival embrasures. Figure 27 shows the lingual aspect of the bridge on the soft tissue model. Figure 28 shows the bridge seated intraorally, and the excellent esthetics that can be achieved with the Cercon® Smart Ceramics™ system.

**Case 4**

A 48-year-old man presented with a mandibular stayplate replacing teeth Nos. 23,
24, 25, and 26. Figure 29 shows the mandibular bridge from teeth Nos. 22 through 27 that was fabricated on a single, solid, milled Cercon® framework. Currently Cercon® is the only all-ceramic system that can fabricate a bridge with four splinted pontics. Again, the maximum framework length with Cercon® is 38 mm, and most mandibular cuspid-to-cuspid bridges will fit within this length requirement.

Small connector sizes make it easier for the technician to achieve ideal esthetics, especially on anterior bridges.

**Case 5**

A 51-year-old woman presented with two PFM crowns on her two maxillary right molars. The gingival tissue around the two existing crowns, particularly adjacent to the lingual metal collar, appeared inflamed and cyanotic. A call to the patient’s previous dentist revealed that the existing PFMs were fabricated from base metal. These crowns were removed and two Cercon® all-ceramic crowns were placed. Figure 30 shows the 2 single Cercon® units 4 weeks after cementation, and the gingival inflammation has disappeared.

**Conclusion**

The cases presented in this article highlight several clinical situations in which the Cercon® Smart Ceramics® system can fulfill both the functional and esthetic needs of the patient. By taking advantage of the strength, toughness, reliability, and biocompatibility of zirconium oxide and the accuracy and control of a CAM process, Cercon® is the only commercially available CAM in the US dental market with the ability to mill a presintered zirconia block into a high-strength, esthetic, biocompatible, and metal-free multiple-unit restoration. This is particularly beneficial to several patient groups, including those patients with metal allergies, those who are metal-phobic, and those with esthetic concerns.

Cercon® is indicated for the fabrication of anterior and posterior single-unit crowns, and bridges with a maximum span of 38 mm. The preparation is accomplished in accordance with the general principles common to most all-ceramic systems. By using a traditional wax-up, the Cercon® system allows laboratory techni-
icians to impart their technical expertise when designing connector size, shape, and placement. The coping thickness of Cercon® gives the technician the maximum amount of space to develop the esthetics of the restoration. Another benefit of Cercon® restorations is that they can be placed with either conventional cementation or adhesive bonding techniques.

In the restorative armamentarium in which all-ceramic restorations have become a welcome addition, the Cercon® system is able to offer unique benefits to both clinicians and their patients seeking esthetic, metal-free, single- and multiunit restorations.

References