QUIZ ARTICLE

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By Lee Culp, CDT and Lida Swann, DDS

Zirconia's Esthetic Evolution

Biomaterials in dentistry must address several requirements that include biocompatibility and strength related to intended purpose and esthetics. The history of dental prostheses reflects a progression from function to esthetics with gold restorations being largely replaced by porcelain fused to metal restorations during a period from the 1970's to 1990's. The introduction of various all-ceramic restorations beginning in the 1980's initiated a continuous transition from metal-based ceramics to different multilayered and monolithic all ceramic restorations.

Figure 1 Early monolithic restoration, showing apparent opacity and high value.

The central issue for all ceramic restorations has been the balancing of esthetics (color and translucency) with strength or function. Different materials have been utilized and their esthetic value traditionally has been inversely related to strength. The basis for this clinical paradox is the use of glass phase ceramics to impart translucency to dental ceramics and the use of relatively opaque crystalline ceramics to achieve strength.

Despite the early esthetic limitations of zirconia-based restorations, the dental profession has seen remarkable penetration into the dental laboratory and clinical practice. The reason for this replacement of metal and metal ceramic restorations is attributable to several factors including the relative cost of gold alloys, the integration of zirconia materials into the CAD/CAM workflow, and the esthetic value of 'white' dental materials. Suggested by this migration of clinical preferences from metal ceramics to all ceramic materials is the satisfactory performance of the all-ceramic material.

The past decade of clinical research has provided some insight regarding the performance of zirconia prostheses. A systematic review by Raigdroski looked at the survival and complications of zirconia FDP. He reported survival rates that ranged from 73.9% to 100% within 12 studies. Five studies reported 100% survival rates during the observations period. One study reported 73.9% survival of frameworks and the rest (six studies) had survival rates ranging between 88.2% and 96.6%. The common complication reported was chipping and it was suggested that with the development of new layering porcelains better clinical properties would be expected.[2]

In a second report, a 2010 systematic review on the performance of zirconia-based fixed dental prosthesis evaluated not only the survival but also the complication rates for this type of prosthesis up to five years. Three hundred and ten prosthesis were included. The 5-year survival rate for all FDP was 94.29% and 76.41% were considered free of complications with chipping being the most reported complication. [3] Very rarely do we seem to see fractures within the zirconia framework itself. For example, the systematic review by Sailer[4], indicated that compared to chipping rates of 13.6%, framework fractures occurred only 6.5%. Observed fractures were reported most commonly in connectors of multiunit posterior restorations, and, or second molar abutments. Larsson's systematic review in 2014[5], suggested that the success rate of tooth-supported and implant-supported zirconia-based crowns is similar, and comparable to that of conventional porcelain-fused-to-metal crowns. A recent laboratory study utilized indentation to induce chipping of monolithic zirconia and lithium disilicate materials. The results confirm that ceramic veneered-zirconia displayed high chipping and monolithic lithium disilicate resisted this chipping; monolithic zirconia was most resistant to this induced chipping behavior.[6]

As revealed in the aforementioned reviews concerning zirconia restoration performance, one of the early and prominent observations made regarding the clinical performance of zirconia-based all ceramic restorations was chipping of the veneering porcelain from the zirconia frameworks. While many different investigators have suggested fundamental reasons for this phenomenon, the clinical response to chipping is a concern for layered zirconia restorations.

When used as a framework, zirconia has an inherent basic esthetic value, due to the fact that it is white and can be alternatively colored to mimic surrounding dentin. Further, it can be provided with high opacity to cover discolored teeth and implant components.[7] This can be advantageous to the technician who is trying to conceal a dark underlying tooth structure, a metal post, or the remainder of amalgam restorations left after initial preparation.

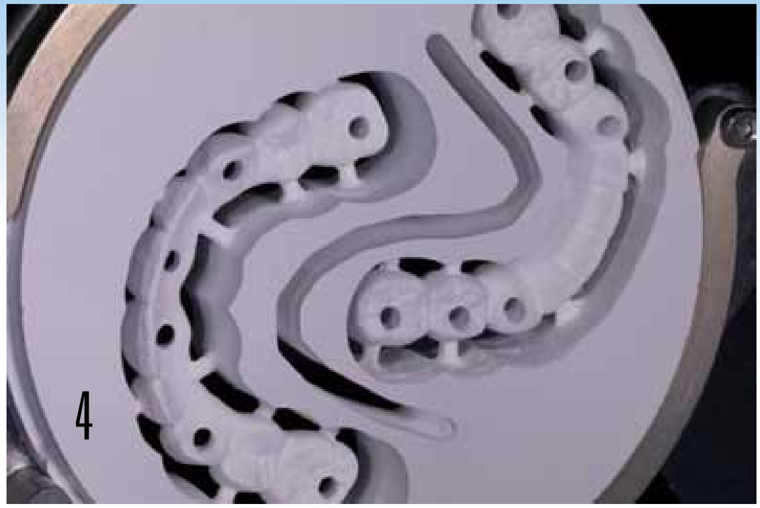
Figure 2
Next evolution of zirconia offers high strength, better translucency. But, still requires ceramic layering on the facial to achieve high esthetics.

Zirconia framework-based restorations, when veneered with an appropriate ceramic layering system designed for zirconia, can result in exceptional aesthetics and can achieve an imperceptible match to the surrounding dentition. The talented technician may develop appropriate color and optical properties of the restoration within the veneering ceramics. However, the past decade of investigation has revealed that chipping within the veneering ceramic or at the framework/veneer interface frustrates higher clinical success and survival of these restorations. Veneer chipping, not framework fracture, appears to be the weak link in zirconia-based restorations.

1.1 Biocompatibility

Research regarding zirconia as biomaterial was started in the late 1960s. Helmer and Driscoll[8] published the first paper 1969. Christel, in 1988, offered the use of zirconia as an alternative to other materials used at the time to manufacture the ball heads for total hip replacements.[9] Zirconia is still used in this application and other medical prosthetics. Implied was acceptable biocompatibility. Clark showed that zirconia was found to be better than other ceramic biomaterials in use circa 1990, because it possessed higher strength and hardness.

The interaction of zirconia with oral soft tissues may be central to the performance of tooth and



Figures 3-6
Zirconia offers an excellent option for the restoration of implant cases, with digital design and precision milling, screw retained monolithic zirconia (with or without facial layering) restorations can be predictably fabricated.

implant supported restorations.[10] The formation of biofilm on dental prostheses, either natural tooth or implant-supported, is material-related. A recent investigation[11] measured the colonization of dental implant abutments. DNA checkerboard analysis revealed that, compared to zirconia abutment materials, higher total bacterial counts were greater on cast or machined titanium disks after 24 hours. This confirms the work of Bremer et al who showed that biofilm was lowest and thinnest on zirconia compared to lithium disilicate restorations.[12] The clinical impression of low biofilm formation and limited inflammation at zirconia restorations is supported by such in vitro and in vivo studies. Bacterial adhesion has proven to be slightly better than titanium. Scarano reported a degree of coverage by bacteria of 12.1% for zirconia as compared to 19.3% on titanium.[13] Rimindini confirmed these results with an in vivo study where y-TZP accumulated fewer bacteria than Ti in terms of total numbers of bacteria and presence of potential pathogens such as rods.[14] It may be concluded that zirconia materials offer advantages of biocompatibility for use as endosseous biomaterials and oral biomaterials due both to its remarkable strength and durability as well as the surface properties of the material.

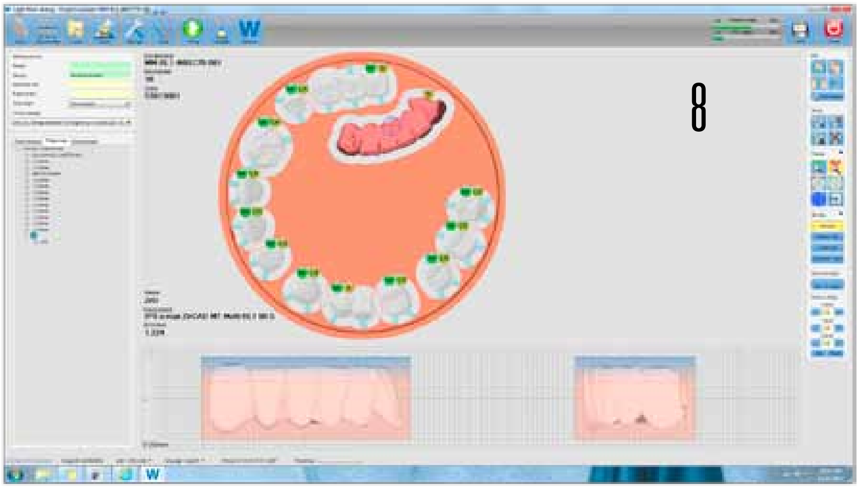
1.2 Strength

Introduction of zirconia-based ceramics as a restorative dental material has generated much interest in the dental profession. The mechanical properties of zirconia are the highest ever reported for any ceramic used prosthetic dentistry. The strength of zirconia has allowed the incorporation of high-strength all ceramics into its use for posterior FDP. [15] High-strength, coupled with the possible high aesthetics that zirconia offers, allows the material to become a highly valuable option in our prosthetic armamentarium.

The basis for the valued strength displayed by zirconia is its unique crystalline structure and its behavior under loads. Zirconium dioxide (ZrO2), also known as zirconia, is a white crystalline oxide of the metal element zirconium. Its most naturally occurring form is the rare mineral baddeleyite; though zirconium metal used for dentistry is obtained from the zirconium-containing mineral ore called zircon. After being processed and purified these powders can be further processed to produce somewhat porous bodies that can be CAD/CAM milled with great precision. Once densely sintered, a polycrystalline ceramic material is produced which, unlike most other dental ceramics, contains no glass phase.

Over the last several years, many high-strength ceramics have been developed for the construction of metal-free restorations.[16] Several studies have evaluated different all ceramic systems and offered conclusions on where these ceramic systems may be used in the oral environment with success. Luthy measured average load bearing capacities for several ceramic systems and found 518 N, for alumina-based restorations, 282 N, for lithium disilicate based restorations, and 755 N, for zirconium restorations.[17] Raigrodski also analyzed several different all ceramic systems, and concluded that the all ceramic systems he studied were only to be used in the anterior, for single crown restorations, and possibly three unit FPDs. He also concluded that because of the higher strength of zirconia, this material offers a wider area of restorative options in the oral cavity, including posterior single units and multiunit restorations.

To circumvent the need for veneering altogether, another option is to develop fracture resistant, partially translucent monolithic ceramics. Monolithic all ceramic restorations are becoming more accepted due to higher strength, by avoiding weak veneer-core interfaces. All ceramic restorations, such as IPS e.max (lithium disilicate), Wieland (zirconia), 3M Lava Plus (zirconia), offer several all ceramic monolithic, restorative options that have acceptable aesthetics and eliminate the need for veneering ceramics altogether.



Figures 7-8
Ivoclar e.max ZirCAD Multi monolithic zirconia, offers both high strength (850 MPa) and esthetics, due to multiple layers of both translucency, and shade within the zirconia restoration.This zirconia requires no ceramic application, as zirconia milling disk is "pre layered."

1.3 Wear

During the early 2000's zirconia was perceived as a material that would cause high wear to the opposing dentition. Today this perception is being challenged[18] and multiple studies have shown how zirconia can be a material gentle to opposing dentition in comparison to glass ceramics that are layered on PFM restorations. This low wear property can be attributed to zirconia's microstructure, and its small grain size, that allows for a mirror polished surface to be created that is kind to opposing enamel surfaces. [19-20]

Figures 9-10
Digital design, in 3 Shape CAD design software, using CULP digital tooth libraries.

An in vitro study by Yu-Seok evaluated the wear of enamel opposing zirconia surface. They found that zirconia surfaces appear to be less abrasive to enamel than feldespathic porcelains. They also found that polished zirconia without glazing is less abrasive than zirconia glazed surfaces.[21] A second study by Burgess also evaluated the wear of enamel by full contour zirconia polished and glazed. A wear simulator and producing a 4mm slide at 20 N rate was applied and samples were evaluated using a non-contact 3D profilometer. Although the wear of glazed zirconia was more than polished zirconia, it was still less than commonly used porcelains for PFM restorations.[22]

1.4 Wear of Zirconia vs Enamel

These results were further investigated in a six-month clinical study that evaluated the wear on opposing dentition for monolithic full contour zirconia prostheses. Twenty monolithic crowns were placed in patients and mean vertical loss for specimens, antagonists and contralateral was recorded. Both mean and maximum enamel wear were significantly different between the antagonists of the zirconia crowns and the contralateral antagonists. Under clinical conditions, monolithic zirconia crowns seem to be associated with more wear of opposed enamel than are natural teeth, but the amount of wear is comparable if not less than other ceramic systems. [23]

1.5 Esthetics

The difficulty in achieving predictable excellent esthetics with PFM restorations and the desire for metal-free solutions has led to the increased use of zirconia. The unique optical properties of zirconia require a new and different understanding of how the materials are managed.[24] Translucency and color are important and often inseparable variables for dental restorations, and translucency may be an innate optical property of the zirconia material related to its crystalline structure. Over the past 16 years we have seen a remarkable evolution in the esthetics of full contour zirconia, as raw material manufacturers

Figures 11-14
Milling, sintering, finishing, glaze and polish of monolithic full contour zirconia restorations

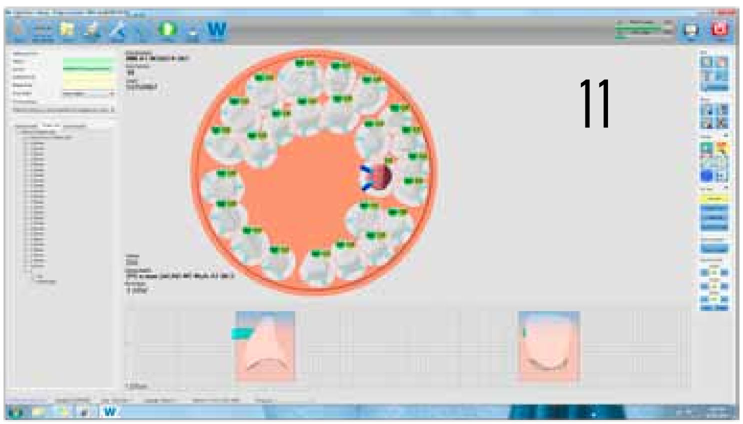


Figure 11
Ivoclar CAM software, offers manual positioning of restoration in e.max Zircad disk, for optimal translucency and esthetics.

Figure 12
Placement of Ivoclar Zircad coloring liquids, for added internal esthetic effects.

Figure 13
Sintered zirconia restoration, showing detailed contour, surface texture, color and translucency.

Figure 14
Final restoration after glazing and polishing.

Figures 15-16
Before images of anterior metal-ceramic restorations.

and ceramic companies work together to improve translucency and optical properties within this unique biomaterial.

At the beginning of our evolution into the use of zirconia, with the use of systems and materials from Cerec, Dentsply Cercon, Vita and Ivoclar and others, we had only one choice in zirconia, white and opaque. Then, as the next phase in our evolution, 3M Lava introduced "dipping coloring liquids" that allowed for the internal coloring of zirconia frames, but we were still layering ceramics to achieve final tooth form and esthetics, and most other companies followed this same direction. But it was not until full contour solid zirconia restorations became popular that serious research into zirconia esthetics became the dominant area of zirconia development. Since then we have seen an amazing phase of evolution in the research/ development on material specification and esthetics of this material that started out as just white and opaque.

In just the last few years zirconia technology has offered the technician both higher translucency and pre-shades disks in all A-D shades. But the real excitement was realized with the new multilayered zirconia milling disks that offer a transition from dentin to enamel shades, along with the proper translucency differences in the areas. These zirconia disks offer the dental technician, dentist and patient a universal restorative option for both anterior and posterior applications that rivals in esthetics traditional hand/brush layered ceramics. **JDT**

Clinical dentistry and photography by Michael Sesemann, DDS

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Figures 17-18
After images of anterior restorations, with monolithic full contour, Ivoclar e.max ZirCAD Multi zirconia.

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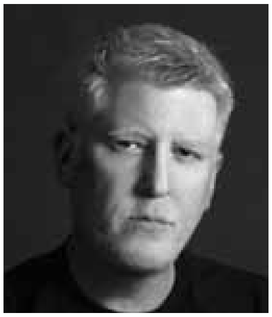

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Dr. Lida Swann received her DDS from Colegio Universitario Colombiano and her Master in Prosthodontics from the University of North Carolina. She was then awarded the UNC Dental - Implant Surgical Fellowship, and then offered a full time faculty position in the UNC Graduate Prosthodontics program. Her educational focus is on implant research and applications of digital technology on implant placement and restorative procedures, and on proper tooth preparation and tissue management for Cad-Cam restorations, as well as materials science with regard to cementation and restorative materials options.

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