Test 87.1

MATERIALS

Use of Zirconia in Restorative Dentistry

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Though zirconia has been available for use in restorative dentistry for several years, there has been an increased interest recently in these materials. Zirconia-based restorations are quite versatile and can be used for crowns, bridges, and implant abutments in a variety of clinical situations if the appropriate guidelines are followed.

The type of zirconia used in dentistry is yttria tetragonal zirconia polycrystal (Y-TZP) material, which is a zirconia oxide. Yttria (Y_2O_3) is an oxide of the metallic element yttrium (atomic No. 39).

Y-TZP is a monophase ceramic material that is formed by directly sintering crystals together without any intervening matrix to form a dense, air-free, polycrystalline structure. The yttria is added to the zirconia to stabilize the structure and maintain the material's desirable properties.

Many dentists are not familiar with zirconia, its differences compared to other materials, the different types that are available, and clinical indications and usage. After reading this article, the reader will have an understanding of zirconia's properties and the knowledge to make appropriate treatment decisions regarding its use.

Both fully sintered (HIP) and partially sintered (non-HIP) zirconia products appear to be clinically acceptable... Caution is urged, however, in regard to the clinical application of this material. Long-term, multicenter studies are needed.

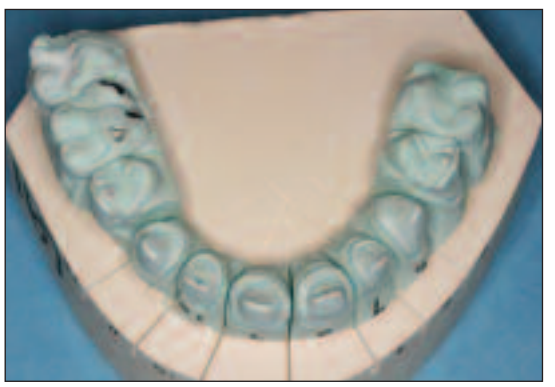

Figure 1. Preparations for single-unit anterior zirconia crowns.

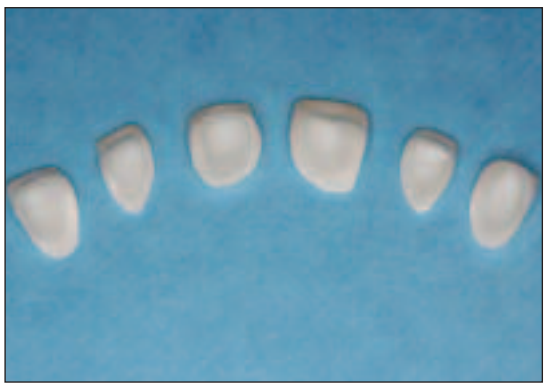

Figure 2. Zirconia copings for anterior crowns.

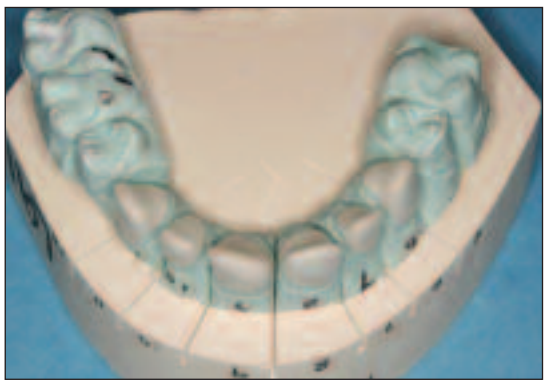

Figure 3. Zirconia copings seated on laboratory model.

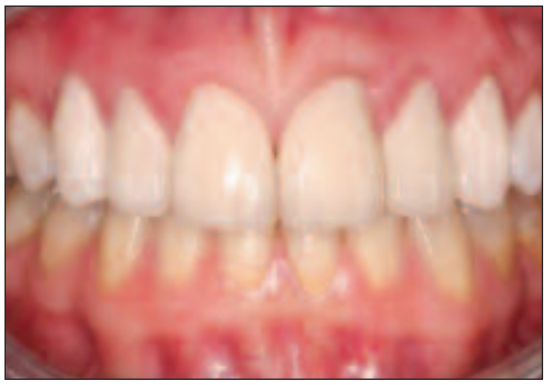

Figure 4. Anterior zirconia-based crowns cemented in place.

PROPERTIES OF ZIRCONIA

The flexural strength of zirconia oxide materials has been reported to be in the range of 900 to 1,100 MPa.[1] This is approximately twice as strong as alumina oxide ceramics currently on the market and 5 times greater than standard glass ceramics.

Even more important is the fracture toughness of the material. Fracture toughness measures the ability of a material to resist propagation of an internal crack (fracture). This is an important indication of a material's clinical reliability.[2] Clinically, non-fatal cracks (cracks that develop in the zirconia but do not result in complete fracture or failure of the restoration) form from cyclic fatigue, which can lead to failure of the restoration if the cracks propagate.[3] Zirconia's fracture toughness is between 8 and 10 MPa $m^{1/2}$,[4] which is almost twice as high as that of aluminum oxide ceramics. This is due to transformational toughening, which gives zirconia its unique mechanical properties. Because of its tetragonal polycrystalline structure, when a crack develops the material transforms to a thermodynamically more favorable monoclinic form. This transformation is associated with a 4% local increase in volume, which produces a "clamping effect" on the crack and halts its further expansion.[5]

In addition, without any glass matrix, zirconia oxide materials are generally stronger and offer more resistance to cracking than other ceramics.[6] Further, chemical corrosion occurs on glass substrates, which can lead to clinical failure. The aqueous component in saliva can react with glass in ceramic material, causing corrosion. This can increase the rate of crack propagation and lead to failure of the material.

TYPES OF ZIRCONIA

Three main types of zirconia are available for use in clinical dentistry. Though they are chemically identical, they have slightly different physical properties (eg, porosity, density, purity, strength), which may (or may not) be clinically relevant.

There is the fully sintered or HIP type of zirconia. HIP stands for "hot isostatic pressing," and is a sintering technique used in the ceramic industry that utilizes high temperatures and pressures to increase density of the material. Examples of this type of fully sin-

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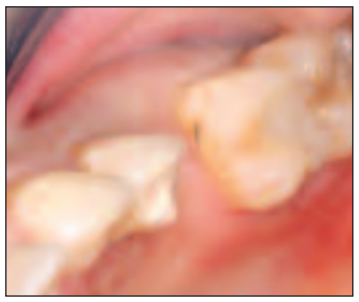

Figure 5. Preoperative view of teeth for fixed bridge.

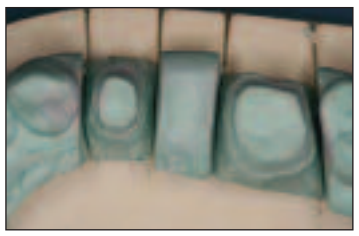

Figure 6. Laboratory model of preparations for zirconia bridge.

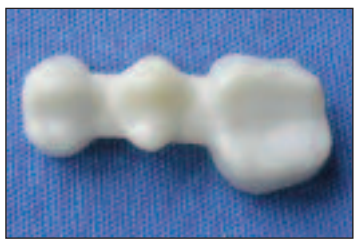

Figure 7. Zirconia framework for bridge for Nos. 12 to 14.

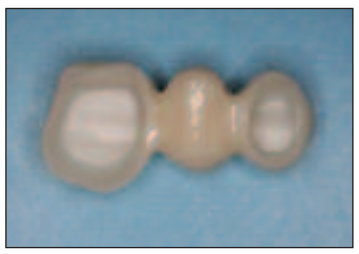

Figure 8. Zirconia bridge framework after veneering with porcelain.

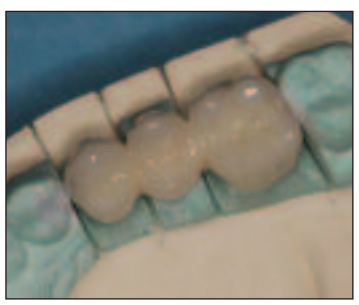

Figure 9. Zirconia-based bridge seated on laboratory model.

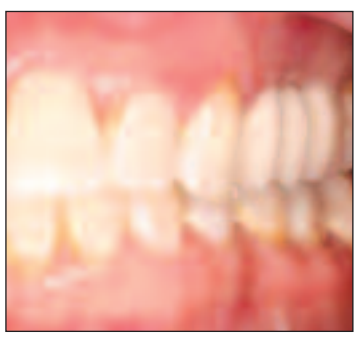

Figure 10. Postoperative view of bridge for Nos. 12 to 14 cemented in place.

tered zirconia are DC-Zirkon (DCS Dental AG) and Everest-ZH (KaVo).

The second type is a partially sintered zirconia, and the third type is nonsintered or "green state" zirconia. Due to the similar manufacturing and fabricating processes, both of these types will be considered together (partially sintered or non-HIP zirconia). Blocks of these types of materials are manufactured by utilizing a spray-dried zirconia powder that is then isostatically pressed and incompletely sintered. These materials remain softer than the HIP zirconia and are easier to mill. After milling, the zirconia is then sintered completely in a furnace at 1,350°C to 1,500°C to achieve its final shape, strength, and physical properties. Examples of this type are Lava (3M ESPE), Cercon (DENTSPLY Ceramco), and Vita YZ (Vident).

Another type of zirconia product is that employed by Nobel Biocare's Procera system. This process utilizes a slurry of zirconia oxide that is applied to an oversized die and then sintered.

FABRICATION

The most common method to fabricate a zirconia substructure is by CAD/CAM milling from a solid block. The fully sintered zirconia is milled at a 1:1 ratio, while the partially sintered zirconia is milled 20% to 25% larger than the desired final size due to shrinkage caused by the sintering process.[7] For both the partially sintered and the fully sintered techniques, the die is scanned, and then the computer program designs the framework or the coping.

After the milling and any necessary sintering, the porcelain is then hand-applied over the zirconia for the restoration's final shape and shade. For clinical success, the layering porcelain ideally should have the same coefficient of thermal expansion as the zirconia substructure, and therefore only specifically engineered porcelains can be used. Porcelain that is used in porcelain-fused-to-metal restorations cannot be used with a zirconia substructure, since delamination will occur. Further, proper firing of a bonding layer of porcelain to the zirconia core is essential to create a stable interface between the 2 materials.[3]

On average, manufacturers recommend that the minimal thickness for a zirconia coping should be 0.3 mm for anterior teeth and 0.5 mm for posterior teeth. For a fixed prosthesis fabricated with zirconia, the cross-sectional dimension for a connector should be 9 mm^2. This is much smaller than the 16-mm^2 connector recommended for conventional glass ceramics. This decrease in connector dimension is due to zirconia's greater strength, allowing for a smaller connector and thus resulting in a more aesthetic appearance.

It is important to note that the laboratory technician plays a very important role in the fabrication process. Identical cases sent to different laboratories produced different results.[8] Clinician's should use a laboratory that has good knowledge of zirconia's properties and a thorough understanding of the entire fabrication process to ensure a successful clinical result.

FULLY SINTERED VERSUS PARTIALLY SINTERED MATERIAL

The question often arises as to which type of zirconia (HIP or non-HIP) is best to use. It appears that they both have their advantages and disadvantages. Fully sintered HIP zirconia has a denser polycrystalline structure with less porosity than non-HIP material,[7] and this should translate clinically into increased resistance to fracture. On the other hand, some investigators have questioned whether the grinding needed to mill the fully sintered zirconia, and the heat that is generated, cause surface and structural defects that can have adverse clinical implications.[9] The marginal fit of either type of material is associated with very acceptable clinical results. The milled margins are the equal of, or are superior to, the fit of a restoration fabricated of a high noble alloy.[8] Studies have measured the marginal gap of CAD/CAM-milled zirconia of both varieties and found that to be 40 to 70 µm.[10]

The manufacturing process for HIP zirconia is more expensive, involves more machining time, and is more labor-intensive to fit the coping than non-HIP systems.[3] As a result, non-HIP systems currently dominate the marketplace.

CLINICAL IMPLICATIONS

Considering zirconia's high strength, this material enables the clinician to place a ceramic restoration almost anywhere in the mouth. Single crowns, implant abutments, and bridges can be fabricated from zirconia.[11,12] Manufacturers suggest that 2 abutment bridges can have a 38-mm span, and multiple abutment bridges can have a span of 47 mm.[8]

Zirconia is a semitranslucent substance that is only slightly more opaque than dentin.[3] By varying the thickness of the coping, the amount of opacity can be controlled. In addition, Lava (3M ESPE) and inVizion (Vident) allow the lab to shade the substructure in the "green state." This allows the color to penetrate the material, as opposed to surface stain, giving the final restoration a natural appearance ("chroma from within").

Zirconia is radiopaque, enabling the clinician to detect more easily improper fit and marginal caries. Additionally, it has been shown to be biocompatible, without any reported cases of toxicity, patient allergy, or sensitivity.[13]

TOOTH PREPARATION

The tooth preparation needed to accommodate a zirconia restoration is essentially that of a porcelain-fused-to-metal crown with a few modifications. The 3M ESPE recommendations for its Lava zirconia is 1.5 to 2.0 mm of incisal/occlusal reduction and 1.0 to 2.0 mm of axial reduction. The range of reduction is related to the aesthetic needs. The more tooth reduction, the more available space for the lab technician to appropriately layer various porcelains to achieve better aesthetics. Some clinicians and technicians advocate 2.0 to 2.5 mm of incisal/occlusal reduction for optimal appearance and anatomical form.[3] The axial

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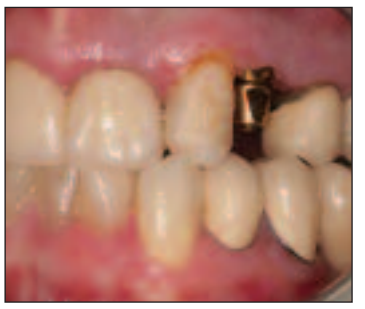

Figure 11. Preoperative view of tooth No. 11 and of implant No. 12 (with transfer coping in place). Note that the patient is missing tooth No. 10.

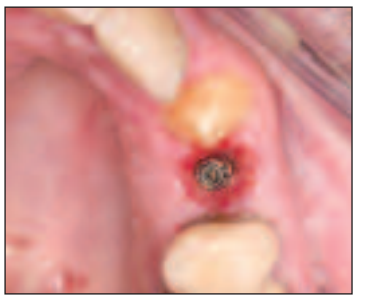

Figure 12. Preparation of tooth No. 11 for zirconia crown.

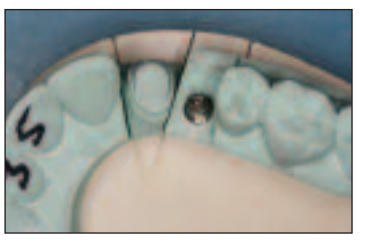

Figure 13. Laboratory model of preparation No. 11 and implant No. 12.

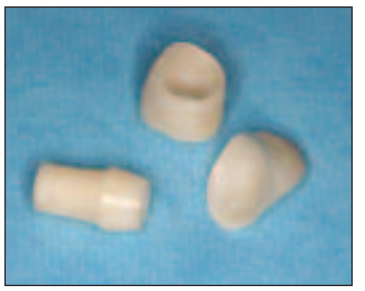

Figure 14. Zirconia copings for crown Nos. 11 and 12 and zirconia implant abutment No. 12.

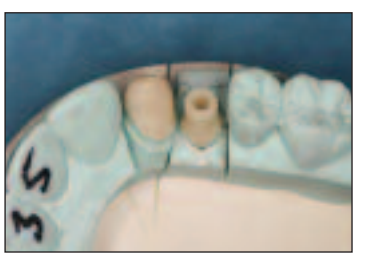

Figure 15. Zirconia coping and zirconia implant abutment on laboratory model.

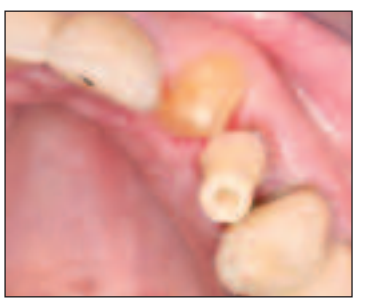

Figure 16. Zirconia implant abutment seated clinically.

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taper should be greater than or equal to 4°, and the horizontal angle of the margin should be greater than or equal to 5°.

Due to the limitations of the die-scanning process and the subsequent machine milling, sharp angles in the preparation must be avoided. A circumferential deep chamfer or rounded shoulder at the gingival margin is recommended. Ninety-degree shoulders, troughing at the margins, feather edge margins, undercuts, or sharp line angles are not acceptable.

AESTHETIC QUALITIES

The metal-free nature of a zirconia restoration is an advantage with regard to aesthetics, but if the preparation is inadequate or the laboratory design is flawed, then the finished crown or bridge can be unappealing. The most common inadequacy is teeth that are not reduced sufficiently. This can result in a restoration that is too opaque and has a monochromatic appearance. Likewise, if the laboratory designs a restoration with a coping that is too thick, or the connectors are too large, the result will be an aesthetically unappealing crown or bridge that looks too bulky.

Due to the inherent opacity of the zirconia, the clinician must be sure that the tooth is prepared adequately to allow enough room for the substructure and the porcelain layer. If this is not the case, then the opaque coping can show through. In addition, if the laboratory technician creates a restoration in which the zirconia is too thick, then there may not be enough space for veneering porcelain. Furthermore, the technician needs to consider the final shade and select an appropriately colored zirconia that allows layering of various translucencies of porcelain to develop a restoration that demonstrates "color from within."

To enhance anterior aesthetics, the clinician can use a rounded shoulder preparation, then cut back the zirconia coping slightly to place a more translucent porcelain at the margin. This allows light to pass through the tooth structure and better blend the restoration/root junction, resulting in a natural appearance.

PLACEMENT TECHNIQUES

Placement of zirconia restorations can be via standard cementation or by bonding. This can simplify the placement process and gives the dentist a number of options.

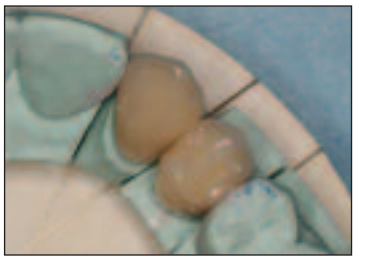

Figure 17. Zirconia-based crowns on laboratory model.

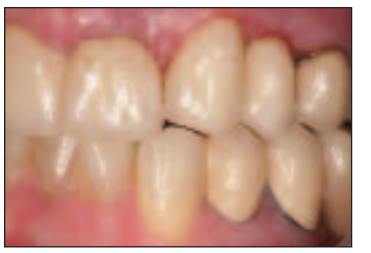

Figure 18. Postoperative view of zirconia implant abutment and crown Nos. 11 and 12.

Due to zirconia's inherent strength, conventional cements like zinc phosphate or polycarboxylate can be used. These cements may not be the first choice, however, due to their physical properties as well as their opaque nature. Opaque cements may show through the zirconia and affect the final appearance of the restoration. Glass ionomer, resin-modified glass ionomer, and self-etching resin cements have all been used with success,[14,15] and these have the potential to enhance aesthetics. Further, with these cements the clean-up of the excess cement at the margin is easy, and elimination of excess cement is always clinically beneficial.

In the case of short or extremely tapered preparations, a bonded resin cement may be best. The problem is how to achieve adherence to the zirconia. Zirconia does not etch with hydrofluoric acid due to lack of a glass matrix, nor does it contain silica to allow silane coupling to occur. By sandblasting the intaglio surface with aluminum oxide particles, a relatively weak bond can occur between the zirconia and the resin.[16] The bond to zirconia can be further improved by using a chemical surface treatment with the Rocatec system (3M ESPE) prior to bonding.[17]

The choice of placement technique ultimately depends upon the clinical situation. The dentist needs to determine how much retention the

preparation provides, the aesthetic demands, the type of restoration being placed, and the location in the mouth.

POTENTIAL PROBLEMS

Failure of dental materials can and does occur in clinical dental practice. All failures cannot be prevented, but the majority can be prevented if both proper material selection guidelines and usage recommendations are followed in regard to preparation, fabrication, and cementation.

The potential problems that can occur with zirconia can be divided into 3 categories:

- substructure failure;
- failure of the bond at the interface between the zirconia and the layering porcelain; and
- breakage and chipping of the porcelain veneer.

Due to the lack of long-term clinical studies, it is difficult to report on the failure rate of zirconia. Anecdotal evidence and limited, short-term clinical studies suggest that the material is clinically acceptable.[18] Some fractures of the porcelain layer have occurred,[18] but the cause has not been determined. Longitudinal studies are needed.

One property of zirconium oxide that has not been well studied is the phenomenon of low-temperature degradation or "aging." Water and nonaqueous solvents are involved in formation of zirconia-hydroxides along a crack. This process accelerates expansion of the fracture and can result in reduced strength, toughness, and density, leading to failure of the restoration.[19]

CONCLUSION

Both fully sintered (HIP) and partially sintered (non-HIP) zirconia products appear to be clinically acceptable. The preparation and cementation protocols are similar to what is used for conventional porcelain-fused-to-metal restorations. Caution is urged, however, in regard to the clinical application of this material. Long-term, multicenter studies are needed. Currently, zirconia appears appropriate for single crowns, anterior implant abutments, and anterior/posterior bridges with one pontic and a span less than or equal to 38 mm (Figures 1 to 18). ✦

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Acknowledgment

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Continuing Education
Test No. 87.1

To submit Continuing Education answers, use the answer sheet on page 112. On the answer sheet, identify the article (this one is Test 87.1), place an X in the box corresponding to the answer you believe is correct, detach the answer sheet from the magazine, and mail to Dentistry Today Department of Continuing Education.

The following 8 questions were derived from the article *Use of Zirconia in Restorative Dentistry* by Richard M. Parker, DDS, on pages 114 through 119.

Learning Objectives

After reading this article, the individual will learn:

- the physical properties of zirconia oxide materials, and
- clinical applications and techniques for zirconia materials.

1. The type of zirconia oxide used in dentistry is composed of ____.
a. a matrix-free, dense polycrystalline material
b. ceramic crystals embedded in a glassy matrix
c. a leucite-reinforced pressed ceramic
d. a metal and glass heterogeneous mixture

2. Transformational toughening refers to zirconia's ability to ____.
a. produce a "clamping effect" on cracks to stop their continued growth
b. change its physical state when repeatedly heated and cooled
c. exhibit metal-like properties such as ductibility and burnishability
d. transform the veneering porcelain into a zirconia-like ceramic

3. The most common way to fabricate a zirconia substructure is by ____.
a. CAD/CAM technology
b. the "lost wax" technique
c. electrophoresis
d. the plasma-spray method

4. Zirconia restorations demonstrate ____.
a. high flexural strength and high fracture toughness
b. semitranslucency and ability to be cemented
c. radiopacity and good marginal fit
d. all of the above

5. Preparations for zirconia restorations must not have ____.
a. 1.5 mm to 2.5 mm of incisal/occlusal reduction
b. 1.0 mm to 2.0 mm of axial reduction
c. an axial taper of at least 4°
d. sharp, 90° shoulder preparations

6. Bonding of zirconia restorations can be problematic because ____.
a. there is not a glass matrix to acid-etch and they do not contain silica for silanating
b. hydrofluoric acid denatures the tetragonal crystalline structure
c. dental adhesives will not set under zirconia due to chemical inhibition
d. resin cements will expand and fracture the coping

7. The main clinical concern with zirconia restorations is ____.
a. they are too unaesthetic for use in the anterior region
b. they are cost prohibitive to use in daily practice
c. they have been shown to be highly allergenic
d. long-term clinical studies are not yet available

8. At present, recommended usage of zirconia is restricted to ____.
a. single crowns
b. anterior implant abutments
c. short-span bridges
d. all of the above