Continuing Education

INNOVATIONS IN DENTAL CERAMICS: ZIRCONIA

Progress continues toward higher translucency and strength

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Abstract

In an effort to create restorations that mimic the form and function of natural teeth, materials scientists are working to perfect products in ceramic dental restorations. In the early 2000s, dentistry was introduced to zirconium dioxide as a substructure for single crowns and fixed partial dentures. Since then, this material, commonly known as zirconia, has been developed to work with other substances to be more esthetic and stronger. Zirconia formulations and processing are constantly changing, including the methods for characterizing the restorations with improved stains and techniques. This article will discuss the evolution of zirconia as a millable material, recent studies examining factors affecting strength and durability in ceramics, and translucency values.

Learning Objectives

AFTER READING THIS ARTICLE, THE READER SHOULD BE ABLE TO:

- Describe the evolution of zirconia as a millable material for dental laboratories.
- Discuss the importance and measurement of translucency in restorations.
- Understand the advances in higher translucent full-contour zirconia restorations.
- Interpret the ISO classification of different dental ceramic materials.

THE ART AND SCIENCE OF DENTAL MATERIALS are constantly evolving to create more efficient methods of producing stronger and more esthetic restorations. Digital technology plays a large role in this evolution, as most full-service laboratories offer digitally manufactured restorations. Furthermore, a continually increasing amount of caseloads consists of CAM-milled restorations. Several new restorative materials options have been introduced that allow the dental technician to be more time efficient in fabricating beautiful, natural-appearing restorations.

Zirconia is one of the only restorative materials that must be fabricated in the laboratory (or in the dental office) by means of digital technology.

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Zirconium dioxide was introduced in dentistry in the early 2000s as a substructure for single crowns and fixed partial dentures, which subsequently were layered with a veneering porcelain. Commonly referred to as zirconia, zirconium dioxide[1] is now used for a full-contour monolithic single crown and multiple-unit monolithic fixed partial dentures (Figure 1). Initially, partially sintered zirconia blocks were milled and stained, and then the sintering process was completed, using a special oven for 9 to 12 hours. For individual posterior single units, for which esthetics is not as critical, a stained monolithic zirconia restoration has been acceptable.

In the anterior, zirconia was first used as a substructure fully veneered with a likely compatible porcelain. Problems began to surface such as delamination of the veneering porcelains. Chipping and bulk fractures of the veneering porcelain without exposure of the zirconia core were occurring[2,3] (Figure 2). Causative factors for these failures included a disparity between the coefficients of thermal expansion between the veneering porcelain and the zirconia substructure, low fracture strength of the porcelains, framework design flaws, and sliding contact fatigue.[4-6] The bond strength between a feldspathic veneering porcelain can also be affected by the sintering of the feldspathic porcelain itself and the surface treatment of the zirconia substructure.[7] For single and multiple anterior units (fixed partial dentures), several fabrication modifications have changed the framework design. The lingual aspect, for example, can be left exposed and milled to full contour while the facial aspect is milled leaving space for veneering porcelains. Other modifications to the fabrication methods have eliminated, for example, the hand-layering of the veneering porcelain and replaced it with a heat-pressed method similar to the press-to-metal technique.[3,8] In theory, this approach would seem to have an increase in fracture resistance with a reduction in air voids and with fewer firing cycles.[3] Stawarczyk et al[9] (referring to this as *overpressing*) found the fracture loads of PressX Zr Dentine Press Pellets (Ivoclar Vivadent, ivoclarvivadent.us), GC Initial LF (GC America, gcamerica.com), and VITA PM9 (VITA North America, vitanorthamerica.com) were not statistically significant between overpressed and layered porcelain systems. Only IPS e.max® ZirPress (Ivoclar Vivadent) was found to have a significantly higher fracture load than the TP value of human dentin is 6.6 and 11.6 for enamel,[20] whereas a material with a value of zero is absolutely opaque.[21] A higher TP value translates to a higher translucency.

The CR, meanwhile, is a measured difference of white-light reduction from a specimen placed over a black (Yb) and white (Yw) background.[22] The contrast ratio is calculated as CR = Yb/Yw. The lower the CR value, the higher the translucency. Therefore, as the level of translucency of a material becomes greater, the TP value increases and the CR decreases.[23]

A natural tooth is comprised of high translucent light-transmitting enamel and a lesser translucent, more light-scattering dentin.[24] The level of translucency of enamel and dentin depends on the wavelength of the emitted light. A higher wavelength translates to a higher translucency value.[25] The goal of ceramic manufacturers is to produce a restorative material that approaches the optics found in nature. The translucency level of dental porcelains is determined by the size, chemical nature, and amount of crystals in the matrix.[26] The translucency in zirconia is derived from the level of alumina particles, impurities, and structural defects that cause the light to scatter. When the source of light-scattering particles decreases, the level of translucency increases.[27]

The thickness of ceramic material also affects the translucency. Wang et al[28] reported that as the thickness of the ceramic material increases, the degree of translucency decreases. Therefore, the type of zirconia used for full-contour restorations, having a greater thickness than the veneered porcelain-to-zirconia, must be modified to create the translucency required.

The strength of zirconia increases with the addition of alumina.[29] However, because alumina has a different refractive index[30] than zirconia, translucency diminishes. A number of manufacturers have introduced new formulations of full-contour zirconia restoratives that have varying degrees of translucency and strength.

3M™ ESPE™ (3mespe.com) changed the distribution and content of aluminum oxide in Lava™ to 0.1 wt%, creating a more translucent version and at the same time maintaining the strength of the product. The new Lava Plus High Translucency Zirconia still has less translucency than glass ceramics but has four times the strength.[31]

Sagemax Bioceramics Inc. (sagemax-dental.com) introduced its first line of zirconia, NexxZr-White, in 2011. That product has a biaxial flexural strength of 1150 MPa. In 2013, Sagemax launched

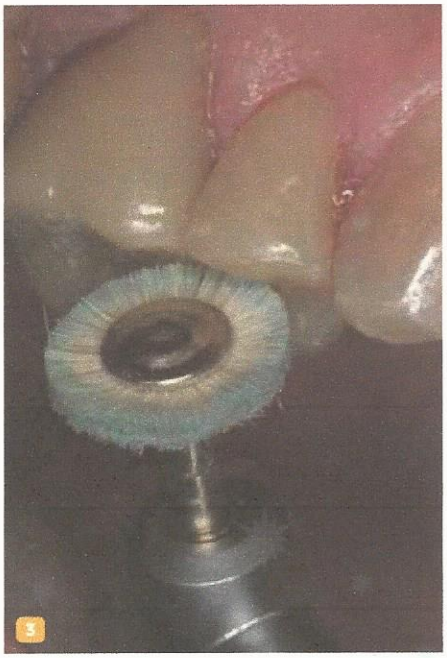

Fig 3 A disposable Zircon-Brite diamond-polishing paste impregnated-bristle brush that eliminates cross-contamination.

a pre-shaded version called NexxZr-19 Pre-shaded that has a flexural strength of 1300 MPa and is available in 19 shades. For milling purposes, the position of the restoration can be adjusted in the milling disc depending on the amount of color required throughout the restoration. This year, Sagemax introduced NexxZrT, which has a biaxial flexural strength of 1150 MPa, a 35% 1-CR translucent factor (1 mm), and a 50% light transmission at 0.6 mm thickness. This version has the most translucency in the incisal area.

Zenostar® Full Contour Zirconia (Ivoclar Vivadent) is available in 6 pre-shaded milling discs. The Zenostar Zr Translucent has a 40% light transmission at 0,6-mm, with less than 0.1% aluminum oxide and a flexural strength of 1200 MPa.

BruxZir® (Glidewell Laboratories, glidewell-dental.com) is another zirconia restorative that can be utilized as a full-contour material. With an average flexural strength of 1200 MPa, BruxZir milling discs are also available in pre-shaded versions.

Bunek et al[32] measured the translucency of 4 unshaded full-contour zirconia ceramics—BruxZir, Lava Plus, NexxZr T, and Zenostar—at thicknesses of 0.5 mm and 1.0 mm. The TP value was calculated using a ColorEye spectrophotometer (X-Rite, xrite.com). With wavelength ranges from 360 nm to 750 nm, BruxZir was the most translucent among the 0.5-mm specimens. In the 1.0-mm specimen samples, BruxZir and NexxZr T were more translucent than the other two. The results showed that all specimens were more translucent in the thinner-version samples, which were similar to the findings of Wang et al.[28]

Newer Improvements

The esthetic qualities of full-contour zirconia restorations increase with a reduction of the porosity,[33] decrease in the grain size,[33] and adjustments to the block or disc processing technique[34] and sintering parameters.[35,36] Klimke et al[37] found that a particle size smaller than 40 nm was necessary to achieve a light transmittance of 50% through a specimen with a thickness of 1.0 mm.

Manufacturers of dental ceramics have always focused on strength and esthetics in their development of restorative materials. A move toward monolithic restorations is a viable approach to eliminating the risk for failures. The creation of translucent ceramics with the highest strength continues to be a high priority. Zirconia formulations and processing are constantly changing, including the methods for characterizing the restorations with improved stains and technique.

Currently, fully stabilized cubic zirconia (ZrO^2) is drawing interest because of the high refractive index. Although the flexural strength of the cubic form is approximately 700 MPa, which is significantly less than the tetragonal form, this version of zirconia is still stronger than lithium disilicate (400 MPa)[38] and similar in translucency.

Recently introduced, cubeX² Cubic Zirconia (DAL DT Technologies, daltechsystems.com) is a full-contour zirconia milling material utilizing the cubic form of zirconia. The approach that cubeX² Cubic Zirconia uses to achieve a higher level of translucency is different in terms of formulation. In order to increase the translucency of standard zirconia (30% translucency), 5 mol% yttria has been added to the 3 mol% yttria (standard zirconia formula) in a combination of 53% cubic form to 47% tetragonal form, which makes the material 19% more translucent. The addition of the cubic form allows for more light absorption, achieving a higher level of translucency, whereas the tetragonal form reflects more light, leading to opacity. So by increasing the amount of the cubic form and decreasing the amount of the tetragonal form, the level of translucency increases. According to the manufacturer, this highly translucent cubic/tetragonal combination has a flexural strength of 720 MPa (Type II Class V) and can be used in full contour for single units and 3-unit bridges in all areas of the mouth.

Another new material, Imagine™ (Jensen Dental, jensendental.com) is a Y-TZP (yttria stabilized tetragonal zirconia polycrystalline), a high translucency material that meets the International Standards Organization (ISO) 6872:2008 requirement of a Type II Class V ceramic with a flexural strength of 760 MPa, according to the manufacturer. It can also be used in full contour for single units or 3-unit bridges or as a coping or framework.

Surface Finish

As with all types of full-contour zirconia restorations, the structural integrity is affected by the surface finish.[39] Manawi et al[40] found that ground, finished, and polished zirconia had a lower flexural strength and fracture toughness than glazed zirconia. After glazing, a smooth topographic surface could not be reached even after finishing and polishing. Clinically, most dental offices do not have the capability to re-glaze zirconia after occlusal adjustments are made. Therefore, it is paramount that the finishing and polishing process be easy for the clinician to provide. To remove diamond bur marks, most manufacturers recommend diamond-impregnated rubber points and discs for finishing surfaces after occlusal adjustments are made chairside. Miyazaki et al[41] reported that a diamond paste was essential in reducing the surface roughness and gloss to an adjusted zirconia surface. For the dentist, a disposable brush has now been impregnated with a diamond polishing paste (Zircon-Brite, Dental Ventures of America, dentalventures.com) and can be used for the final step in restoring the zirconia surface. These RA latch-type brushes provide the clinician with the access to apply the diamond polishing paste for 2 to 3 restorations without the concern of cross-contamination (Figure 3).

Standards and Classifications

Often, restorative materials are labeled with an ISO classification type and number. Numerous standards organizations exist throughout the world. In the US, a major one is the American National Standards Institute, which officially represents the US in the ISO.[42] A number of technical societies and organizations representing specific fields contribute data. For example, the American Dental Association has developed standards in the US and accepts the worldwide ISO standards.[42] In 2008,[43] the ISO revised its 1995 standard for dental ceramics (ISO 6872:1995) to ISO 6872:2008, in which Clause 4 specifies 2 ceramic types: Type I ceramic products, which are provided as powders, pastes, and aerosols; and Type II, which includes all other forms of ceramic products such as millable zirconia blocks and discs. This standard further categorizes ceramics by a classification based on flexural strength.[44] Class I ceramics are for esthetic coverage of metal or ceramic substructures and single-unit anterior restorations, including veneers, inlays, and onlays, and should have a minimum flexural strength of 50 MPa. Class II ceramics are esthetic ceramics for adhesively cemented restorations used in the anterior and posterior regions and adhesively retained anterior and posterior ceramic substructures with a flexural strength of 100 MPa. Class III ceramics are nonadhesively retained anterior and posterior single units with a flexural strength of 300 MPa. Class IV ceramics are nonadhesively retained single-unit substructures used in the anterior and posterior regions having a flexural strength of 300 MPa. This class also includes 3-unit ceramic substructures not involving molar restorations. Class V ceramics include 3-unit substructures that do involve molar restorations and have a flexural strength of 500 MPa. Finally, Class VI ceramics include 4-or-more-unit substructures with a flexural strength of 800 MPa.[44]

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This clarification of the ISO 6872:2008 standard allows the reader to discern the labeling of restorative materials that is found in the manufacturers' information packets.

Conclusion

The new milling products available continue to improve the quality and esthetics of restorative materials with greater longevity and diminishing the failure rate. Manufacturers continue to progress in the development of dental restorative materials benefiting not only the clinician and technician but also, most importantly, the patient.

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