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The use of zirconia in crown and bridge restorations

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Abstract

During the past sixty years, zirconia as a restoration have been successfully introduced into the clinical and laboratory work to fabricate both fixed and removable dental prostheses. Furthermore, the rapid advancement in computer-aided/computer-aided manufacturing (CAD/CAM) systems has also contributed in the success of this material. Zirconia represent one of the best choices in dental materials from the esthetic point of view when compared to metallic and ceramo-metallic restorations. This is because of its relatively high strength and fracture resistance in addition to the high stability in color and biocompatibility by its high hardness which allows it to maintain high surface polish and prevent plaque retention. This review illustrate the different types of zirconia and its use in crown and bridge restorations.

Keywords: Computer-aided/computer-aided manufacturing, bridge restorations, crack propagation

Introduction

Classification of dental ceramics

Four broad categories can be used to group dental ceramics. The first group is made up of glass-based systems, which have a flexural strength of 70-100 MPa and are primarily made of silica (SiO₂). Glass-based systems with fillers fall under the second group, which is further divided into feldspathic glass with low to moderate amounts of leucite, glass with large concentrations of leucite, and most recently, lithium-disilicate glass ceramics. Leucite or lithium disilicate are used as crystalline fillers in this category, which primarily consists of silica. Due to the crystalline fillers' ability to prevent crack propagation, the flexural strength is higher than that of glass-based systems, which ranges from 120 to 300 MPa^[1].

The crystalline-based systems with glass fillers fall into the third group and are mostly made of alumina or zirconia toughened alumina with a small amount of glass fillers. The proportion of crystalline or zirconia-toughened alumina climbed to a high level, exceeding 300 MPa, but it also resulted in a notable loss in translucency^[1,3].

The polycrystalline solids category, which is made up of oxide ceramics, is the final fourth category. Zirconia (ZrO₂) or alumina (Al₂O₃) are two options for oxide ceramics. Flexural strength for the alumina-based kind ranges from 275 to 700 MPa. While the flexural strength of the zirconia-based kind is 800 to 1500 MPa^[1].

The strongest ceramics, made of closely packed polycrystalline oxides without any glassy elements, are alumina and zirconia. Zirconia is stronger than alumina, and it has a fracture toughness that is roughly twice as high^[4].

Zirconia's high mechanical qualities make it more appropriate for use as an abutment in implant dentistry. Phase change of crystals is the primary cause of this significant improvement in zirconia's mechanical characteristics. Zirconia contains monoclinic crystals that are 4.5% larger in volume than tetragonal crystals when it is at ambient temperature. Tetragonal crystals are created at firing temperatures between 11700 and 23700 degrees Celsius. Zirconia's tetragonal crystal structure was able to be stabilized at ambient temperature by the addition of yttria (Y₂O₃)^[5].

Tetragonal zirconia stabilized by yttria is the name of this substance. The ability of this material to change its crystalline structure at ambient temperature in response to stresses like those experienced during fracture propagation is its most significant quality.

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When such forces are present, yttria-stabilized tetragonal zirconia can change its crystal structure from tetragonal to monoclinic. This significantly improves its capacity to withstand these forces. The increase in volume brought on by this material's metamorphosis into crystals absorbs pressures. This causes internal compressive stresses to boost the material's flexural strength by compensating for internal tensile stresses that contribute to crack propagation [6, 7].

Zirconia Ceramics

Adding oxygen to the pure, elemental metal of zirconium results in the formation of zirconium dioxide (ZrO_2), a glass-free ceramic substance [8]. Zirconia, which comes in polycrystalline form, has a high flexural strength of between 900 and 1200 MPa as well as a high fracture toughness. It is a white, opaque substance. Zirconia lacks a glassy phase, which reduces the efficacy of the standard etching with hydrofluoric acid to promote adhesion. As a result, various surface treatments, including selective infiltration etching and airborne abrasion have been found to strengthen the binding between zirconia ceramics and resin cement. The requirement to veneer bi-layered zirconia dental restorations with reduced strength glass ceramics makes them vulnerable. The veneer

ceramic layer chipping is the system's most often reported failure occur [9-13].

Dental restoration frameworks can be made utilising either soft or hard CAD/CAM machining. ZH (KaVo), Everest ZS and Lava Frame (3M ESPE), in-Ceram YZ (VITA), Cercon Smart Ceramics, and Zerion (Straumann) are some examples of (Y-TZP) blocks (DeguDent) [14, 15].

Yttrium-tetragonal zirconia polycrystal ceramics (Y-TZP)

At different temperatures, zirconia exhibits 3 crystallographic phases: A cubic phase, which is stable from 2680-2370 °C, a tetragonal phase, which is stable from 2370-1170 °C, and a monoclinic phase which is stable from 1170 °C to the normal room temperature [6].

Transformation results in a significant volume increase (4%), high internal stress, and perhaps severe cracking [16, 17]. At room temperature, partially stabilised zirconia (PSZ) is formed when small components like yttrium oxide (Y_2O_3), calcium oxide (CaO), or magnesium oxide (MgO), are added to pure zirconia. Zirconia can now be used in dentistry thanks to developments in CAD/CAM technology. There are two CAD/CAM processing methods available for zirconia blanks: Hard Processing and Soft Processing [17, 18].

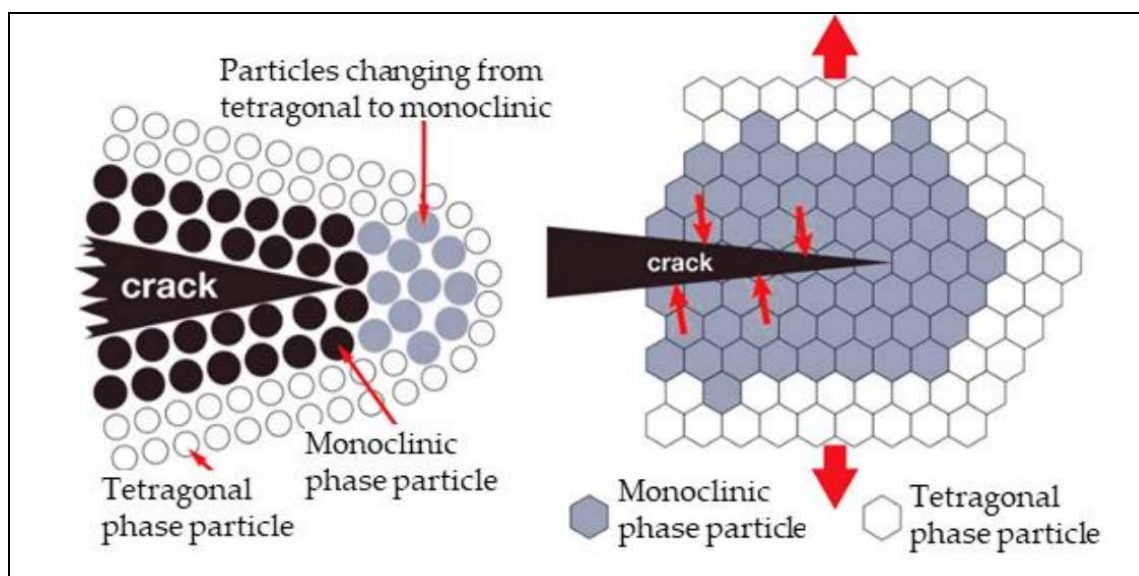


Fig 1: Transformation toughening mechanism in zirconia [17].

First, fully sintered zirconia blanks are milled to the appropriate framework form and decrease. Sadly, fully sintered zirconia necessitates specialized milling tools and prolonged processing durations [19, 20]. The second technique involves milling blanks of partially sintered zirconia. After the last sinter fire at 1300-1500°C for roughly 2–6 hours, larger frames are created utilizing CAD/CAM technology to account for material shrinkage of 20-25% [21, 22].

In order to process pre-sintered zirconia, the most popular CAD/CAM systems are Procera (Sweden Nobel Biocare, Gothenburg), LAVA (Germany 3M ESPE, Seefeld), CEREC (Germany Sirona, Bensheim), and CERCON (Germany Dentsply Friadent, Mannheim). Lately, fully anatomic, monolithic zirconia ceramic restorations were developed for posterior teeth that experience high stress loads in order to prevent chipping failure caused by glass-ceramic veneering.

All-zirconia monolithic restorations such as BruxZir Solid Zirconia (USA Gildewell labs, California), ZirkonZahn (Italy PRETTAU GMBH, Bruneck), and Lava all-Zirconia (Germany 3M ESPE, Seefeld) have been released on the market. Manufacturers claim that patients with parafunctional habits or restricted occlusal space should fabricate posterior single crown restorations using all-zirconia monolithic restorations. Zirconia is an opaque, high-value, substance, thus coloring the restoration before sintering is necessary [23, 24].

Monolithic zirconia restorations

For addressing issues with porcelain layers chipping placed over zirconia, yttria stabilised tetragonal zirconia polycrystal (Y-TZP) for monolithic (full-contour) restorations was developed lately of the polycrystalline ceramics [25, 26].

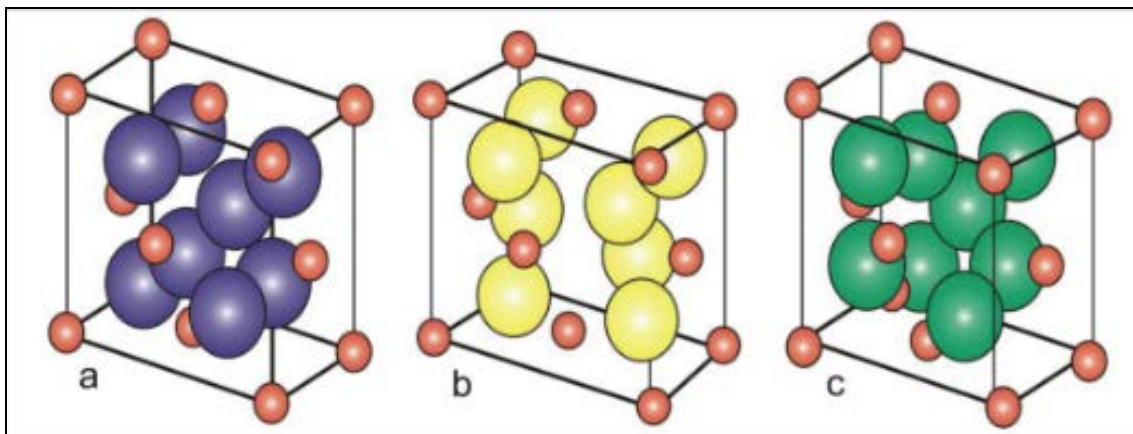


Fig 2: Crystal structure of zirconia: A) Monoclinic zirconia. B) Tetragonal zirconia. C) Cubic zirconia ^[27]

Cubic, tetragonal, and monoclinic phases are the three distinct crystallographic forms of zirconia. Due to its high strength levels of more than one thousand MPa and its higher fracture toughness, Y-TZP exhibits superior performance when compared to other dental ceramics. The result of the toughening mechanism linked to the conversion of the tetragonal grains into a monoclinic phase that generates compression stresses around the defects and prevents their catastrophic propagation, is particularly high fracture

toughness. When compared to traditional Y-TZP, the microstructure of Y-TZPs for monolithic prosthesis has been optimised to increase translucency. Microstructural changes, such as a reduction in alumina content, an increase in the density, a reduction in grain size, the addition of the cubic zirconia, as well as a decrease in the number of impurities and structural flaws, were used to improve the translucency of the new zirconia materials ^[28, 29].

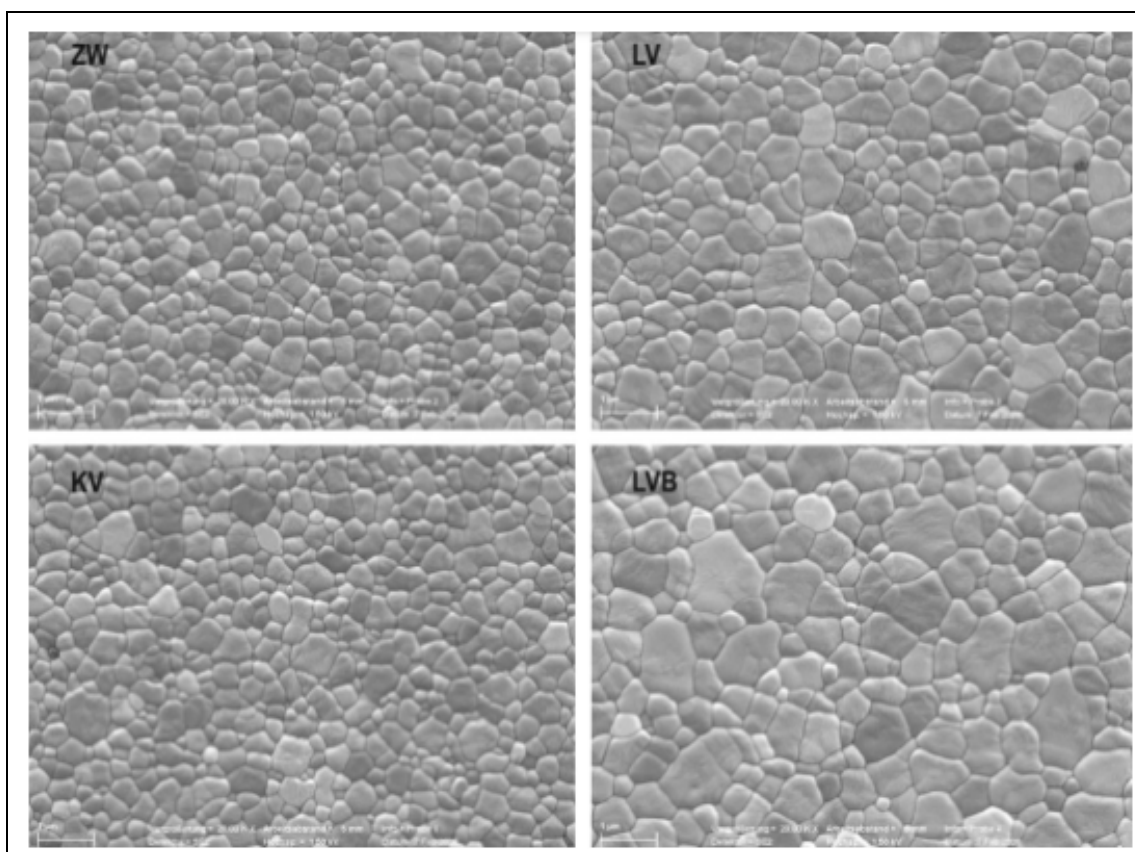


Fig 3: The four Y-TZP ceramics' microstructures (20,000). The 'Linear interceptive count method' revealed the following about the average grain size: Lava (LV) 537 nm (47), Zeno (ZW) 383 nm (47), Everest (KV) 383 nm (47), and Lava colored (LVB) 643 nm (61) ^[30].

The microstructural characteristic that is most closely linked to the control of polycrystalline ceramics' translucency is the size of a crystalline grain. In the past, increasing a grain size during sintering has been used to produce ceramic materials with great translucency ^[31].

Light scattering is decreased because larger grains result in fewer grain borders. Larger grains have been proven to be deleterious to the mechanical characteristics of Y-TZP. Since

zirconia has relatively strong mechanical qualities, particularly when compared to the veneering porcelains, monolithic restorations constructed with this ceramic material allow doctors to undertake far less invasive preparations from a biological perspective. In fact, crucial microstructural mechanisms like toughening during transformation prevent cracks from spreading through restorations, allowing for the construction of smaller structures while yet protecting tooth

tissues. Due to the advancement of CAD-CAM techniques, the marginal adaption of the monolithic restorations of Y-TZP has gotten better over time. Zenostar Zirconia (Germany Wieland, Pforzheim), Ceramill Zolid White (Austria Amann Girrbach, Koblach), TZ Incoris. (Germany Dentsply-Sirona, Bensheim), Bruxzir Solid Zirconia (Germany Glidewell, Gais) and Prettau Zirconia (Zirkonzahn) were some of the systems and materials whose adaptability was examined [32, 33].

Therefore, one of the following materials may be used in anterior crowns and veneers: Ceramics made of glass, such as e-max Press, IPS Empress, and the Feldspathic porcelain series. Ceramics made from alumina, such as Procera All Ceram, In-ceram Zirconia, In-ceram Spinell, and In-ceram Alumina. Ceramics Based on Zirconia [34]. Investigations were done into how pretreatments affected zirconia ceramic leaking. There has been no statistically significant changes between the groups of zirconia ceramics treated with the Nd: YAG laser, silica coating group, airborne aluminium oxide particle treatment, or application of a zirconia primer [35].

Increasing translucency of zirconia restoration

A solution to the veneer chipping problem was to eliminate the veneering porcelain and use the zirconia alone to produce the full contour of the restoration called a "monolithic" restoration. However, the poor aesthetic quality of conventional monolithic zirconia prevents its use in the form of a monolithic restoration. At this stage, the research and development focus changed from achieving high strength to achieving high aesthetics. As discussed earlier, the properties of zirconia can be altered by changing its microstructure [41].

Methods for increasing translucency of zirconia

Increasing the density: Increasing the density of the zirconia structure, decreasing the pores size and number, enhances the translucency of zirconia (Jiang *et al.* 2011). Pore size in the range of 200-400 nm and pore number of 0.05% significantly reduce the translucency of zirconia [41].

Altering the size of zirconia crystals: The number of grain boundaries that the light beams must travel decreases as crystal size increases, reducing light scattering and enhancing translucency. By increasing the sintering temperature and the dwell time at the peak temperature, the size of the crystals can be increased; the resulting material is referred to as "the first generation of zirconia". There is a limit to how big the grains can go, though, as spontaneous phase transformation happens when the particles are bigger than 1 μ m, which drastically reduces the strength and makes it unsuitable for clinical application. Paradoxically, reducing the crystal size also enhances the translucency according to the Rayleigh scattering model. For high-strength tetragonal yttria-stabilized zirconia to achieve translucency similar to glass ceramics, a grain size of under 100nm is needed [41].

Removing sintering additives: Zirconia's translucency is decreased because Alumina's refractive index is different from that of zirconia, which causes light to be scattered as it crosses the boundaries between the two phases [42]. Zirconia was produced by reducing the alumina content from 0.25wt% to 0.05wt%. However, the translucency of this product was still inferior to that of glass ceramics [42]. The available zirconia products in the market vary in their Aluminium content. Furthermore, there is no agreement on how much Aluminium should be removed to achieve the desired translucency [43, 44].

Increasing the content of cubic phase: No matter which way the crystals are oriented, cubic zirconia interacts with light in a consistent and constant way, making it more translucent [45]. The increased size of cubic zirconia crystals also results in fewer grain boundaries and less light scattering. By raising the amount of Y₂O₃ from 3 mol% (5.18 wt %) to 4 mol% (7.10 wt %) or 5 mol% (9.32 wt %), the amount of cubic zirconia can be enhanced. Once more, the Y₂O₃ content of the zirconia goods that are sold in the market varies, but they are all treated as one material [41].

Conclusion

Zirconia was shown to be a reliable material in both anterior and posterior restoration. The enormous advancement in the material science has overcome many of its disadvantages of zirconia. Zirconia in the anterior zone may provide high esthetic results similar to glass ceramic restorations. In past, the main problem of previous zirconia was opacity and debonding. With recent advancement in dental material science translucency and bonding strength is significantly enhanced.

Conflict of Interest

Not available

Financial Support

Not available

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