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Zirconia Crown as Single Unit Tooth Restoration: A Literature Review

Yasser Alfawaz

ABSTRACT

Ceramics has become increasingly popular as a dental restorative material because of its superior esthetics, as well as its inertness and biocompatibility. Among dental ceramics, zirconia is used as a dental biomaterial and it is the material of choice in contemporary restorative dentistry. Zirconia ceramics has both clinical popularity and success due to its outstanding mechanical properties and ease of machining in the green stage *via* computer-aided design and computer-aided manufacturing technology. Zirconia is one of the most promising restorative biomaterial because it has favorable mechanical and chemical properties suitable for medical application. Zirconia ceramics is becoming a prevalent biomaterial in dentistry. Clinical evaluations also indicate a good success rate for zirconia with minimal complications. This article reviews the current literature on dental zirconia with respect to basic properties, biocompatibility, and clinical applications in aesthetic dentistry as single unit crown.

Keywords: All ceramic restorations, Bond strength, Crowns, Dental ceramics, Fracture resistance, Zirconia.

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INTRODUCTION

Ceramics has become increasingly popular as a dental restorative material because of its superior aesthetics, as well as its inertness and biocompatibility. The name zirconium comes from the Arabic word Zargon meaning golden in color, which, in turn, comes from the two Persian words Zar (Gold) and Gun (Color). Zirconia, the metal dioxide (ZrO_2), was identified as such in 1789 by the German chemist Martin Heinrich Klaproth in the reaction product obtained after heating some gems, and was used for many years, blended with rare earth oxides as pigments for ceramics.[1] It was isolated by the Swedish chemist Jons Jakob Berzelius, in 1824. Zirconium dioxide (ZrO_2), known as zirconia, is a white crystalline oxide of zirconium. Although pure zirconium oxide does not occur in nature, it is found in the minerals baddeleyite and zircon ($ZrSiO_4$). Properties such as good chemical and dimensional stability, along with mechanical strength and toughness, coupled with a Young's modulus similar to stainless steel alloys make zirconia a suitable ceramic biomaterial.[2] Zirconia (ZrO_2) is a polymorphic material that has three allotropes, monoclinic, tetragonal, and cubic phases, which are stable at a different range of temperature. The tetragonal grains are normally stable at high temperatures and can be retained at room temperature by adding metal oxides, such as yttria (Y_2O_3) or ceria (CeO_2).

Zirconia is a polycrystalline ceramic without glass component. Pure zirconium exists in crystalline form as white and ductile metal and in amorphous form as a blue black powder. Among elements in earth's crust, it is 18th in abundance. However, it does not occur in nature in a pure state, but only in conjunction with silicate oxides ($ZrO_2 \times SiO_2$) or as free oxide (ZrO_2).[2]

The demand for aesthetic restorations has resulted in an increased use of dental ceramics for anterior and posterior restorations. Use of zirconia in crowns and bridges has increased over recent years, owing to aesthetic and biocompatibility demands.[3] Moreover, it has excellent mechanical properties which make it more popular in the field of restorative dentistry than other ceramics.[4] The use of zirconium oxide as a core material for full crowns provides better aesthetic characteristics, mechanical properties, and biocompatibility.[5,6]

Department of Restorative Dental Sciences, College of Dentistry
King Saud University, Riyadh, Kingdom of Saudi Arabia

Corresponding Author: Yasser Alfawaz, Lecturer, Department of Restorative Dental Sciences, College of Dentistry, King Saud University, Riyadh, Kingdom of Saudi Arabia, Phone: +96614677420, e-mail: yasseralfawaz@gmail.com

Type of Zirconia used in Dentistry

Although there are many types of zirconia available, only three types are used in dentistry. The first is yttrium cation-doped tetragonal zirconia polycrystals (3Y-TZPs), the second is magnesium cation-doped partially stabilized zirconia (Mg-PSZ), and finally the zirconia-toughened alumina. The PSZ is stabilized with magnesia and in addition to the cubic phase, a transformable tetragonal phase is available. Its microstructure at room temperature is mostly cubic with portions of monoclinic and tetragonal phases, while TZPs have an ultrafine, nanometer-scaled structure that allows the transformation during cooling from the cubic to the tetragonal phase, but not to the monoclinic phase.[7]

Yttrium-stabilized Tetragonal Zirconia Polycrystalline (Y-TZP)

Yttrium-stabilized tetragonal zirconia polycrystalline exhibits high biocompatibility and improved fracture toughness. The Y-TZP zirconia has been used as the framework of all ceramic crowns and fixed partial dentures, implants, abutments, and brackets.[8,9] It has a fine grain structure to improve the mechanical performance. Cercon (Dentsply Prosthetics, DeguDent GmbH, Germany) and Lava (3M ESPE, St. Paul, MN, USA) are dental examples of commercially available material of this type. This is the most used type.[10]

Zirconia-toughened Alumina

Zirconia-toughened alumina belongs to a family of ceramics that have a toughening mechanism due to transformation of the crystal structure under an applied stress. Their microstructures have been tailored to produce a significant enhancement of structural properties over basic alumina materials. This material is developed by adding ceria-stabilized zirconia to In-Ceram alumina. This type has less mechanical properties than Y-TZP. There is only one commercially available for dental practice, which is In-Ceram zirconia. This type can be fabricated from both unsintered and fully sintered zirconia.[2,8,10]

Magnesium Partially Stabilized Zirconia

This is the most studied type of zirconia, but it shows large grain size and more porosity that affect the mechanical properties and cues more wear. Denzir-M Denzir-M (Dentronic AB, Skellefteå, Sweden) is commercially available for dental practice that can be fabricated by fully sintered zirconia block.[11,12]

Zirconia Single Crowns

Zirconia seems to satisfy both esthetic and mechanical needs as a core material for all ceramic restorations.[13] Its mechanical properties are the highest ever reported for any dental ceramic; indeed, this material can exhibit toughness higher than 6 MPa and strength greater than 1,000 MPa.[14] Zirconia has better mechanical properties compared with other ceramics, such as alumina, glass ceramics, and lithium disilicate. It is aesthetically superior and can be used in anterior, premolar, and molar areas. Zirconia crowns have shown a good marginal adaptation, giving the clinician an aesthetic alternative to metal ceramic crowns.[15] The survival rate of zirconia has been shown to be similar to that of metal ceramics for both crowns and partial fixed dental prostheses (FDPs).[16-18]

Biocompatibility of Zirconia Restorations

Biocompatibility of zirconia has been evaluated using *in vitro* and *in vivo* studies, which showed better tissue response with zirconia restorations.[19,20] Cytotoxicity studies with human gingival fibroblast cells showed no cytotoxicity of various ceramics including Denzir (Y-TZP).[21] Cell cultures with cells, such as fibroblasts, blood cells, and osteoblast cells showed no cytotoxic reactions to zirconia material.[2] Piconi et al[22] also tested the different physical forms of the ceramic (powders and dense ceramics) and found no adverse reactions. The chemical solubility test and ageing using 4% acetic acid showed no solubility above the acceptability limit.[23]

CLINICAL IMPLICATIONS

All ceramic materials are increasingly being used for the fabrication of crowns and FDPs. Systematic reviews showed that all ceramic restorations exhibited survival rates similar to those of traditional metal-ceramic crowns.[24] A systematic review of 16 studies, including 830 tooth-supported and 301 implant-supported Y-TZP-based crowns showed cumulative survival rates of 95.9% for tooth-supported crowns and 97.1% for implant-supported crowns.[25] Follow-up studies on the clinical performance of zirconia restorations especially on the premolar and molar region showed no fracture or failure.[26,27] A systematic review on the clinical outcome of single porcelain-fused-to-zirconium dioxide crowns for a period between 24 and 39 months showed the survival rates of Y-TZP crowns ranged from 92.7 to 100%.[6] A comparative 2-year randomized controlled study of zirconia *vs* slip-cast glass-infiltrated alumina/zirconia all ceramic crowns did not show any chipping of the zirconia single crows.[26]

Chipping

The most frequently reported technical problem of the veneering zirconia ceramic is the chipping or fracture which accounts for 8 to 25%.[28,29] Adhesive fracture at the zirconia–porcelain interface occurs less frequently.

This is attributable to thermal incompatibility, mechanical insufficiency of veneering porcelain, and inappropriate framework support for the veneer.[30] These failures may be related to incompatibility between the coefficient of thermal expansion of 3Y-TZP and veneering porcelain, contraction during the sintering process, inadequate cooling rates, insufficient finishing and polishing after occlusal adjustments, and uneven porcelain thickness. The use of new low-fusing ceramics has a thermal expansion coefficient compatible with zirconia.[31]

Ageing

The ageing of Y-TZP zirconia is a low-temperature degradation phenomenon and is characterized by a progressive, spontaneous transformation of the tetragonal phase into the monoclinic phase (T-M), which results in diminished mechanical properties. A slow T-M transformation occurs when Y-TZP is in contact with water or body fluid which leads to surface damage. The color characterization of these graded glass–zirconia restorations is achieved by external residual glass and subsequent staining. Restorations made from graded glass–zirconia are orders of magnitude more resistant to sliding-contact damage than the current porcelain-veneered zirconia systems, thereby averting chips and fractures of the porcelain veneer. The graded layer also enhances the flexural fracture resistance of zirconia, allowing the utilization of thinner restorations for highly conservative restorative protocols that preserve tooth structure. The cementation surface of graded restorations can be etched with hydrofluoric acid and silanized to facilitate a resin–cement bond, greatly improving the cementation strength compared with their ungraded counterparts.[32]

Mechanical Properties

Zirconia possesses good mechanical properties, in particular high fracture toughness and flexural strength.[17,18] Zirconia restorations offer sufficient stability and good clinical performance in terms of fracture resistance, marginal integrity, marginal discoloration, and secondary caries.[33-35] Metal-free, all-ceramic restorations have become more popular due to their high aesthetic potential and their excellent biocompatibility.[36] Zirconia (ZrO_2) is a polymorphic material that has three allotropes, monoclinic, tetragonal, and cubic phases, which are stable at a different range of temperatures. The tetragonal grains of zirconia, which are normally stable at high temperatures, can be retained at room temperature by adding metal oxides, such as yttria (Y_2O_3) or ceria (CeO_2). Experimental findings suggest that restorations made from graded glass–zirconia are orders of magnitude more resistant to sliding-contact damage than the current porcelain-veneered zirconia systems, thereby averting chips and fractures of the porcelain veneer. The graded layer also enhances the flexural fracture resistance of zirconia, allowing the utilization of thinner restorations for highly conservative restorative protocols that preserve tooth structure.[37] A 2-year randomized controlled trial of zirconia single crowns revealed a success rate of 93%. Biocompatibility was excellent with no significant difference in soft tissue health adjacent to the Cercon crowns and the control crowns made with In-Ceram zirconia.[26] The fracture toughness and flexural strength of zirconia are significantly higher than that of alumina or any other currently available ceramic.[27] The industrial dense polycrystalline ceramics such as alumina, zirconia, and alumina–zirconia composites are currently available for use with computer-aided design and computer-aided manufacturing technology via a networked machining center. In particular, Y-TZP shows better mechanical properties and superior resistance to fracture. Yttrium-stabilized tetragonal zirconia polycrystalline has a high fracture toughness and flexural strength.[38,39]

Cementation

Because of its high flexural strength, zirconia can be cemented without the need for any pretreatment. Bonding of zirconia is possible provided special conditioning and treatment of the zirconia is carried out since zirconia is not etchable glass ionomer (GIC), and resin-based cements are the primary choices for bonding ceramic restorations to the remaining tooth structure. Glass ionomer and resin-modified GIC are often used to cement acid-resistant ceramics, mostly because these cements are very easy to use. A range of cements were tested in the studies such as zinc phosphate, GIC, resin-modified GIC, and resin cements.[40] The most common cements for zirconia restorations are the resin-based composites.[41] The resin bonding between a tooth and the restoration is advocated for improving the retention, marginal adaptation, and fracture resistance of restorations.[42]

Studies showed that the clinical success of resin bonding procedures for cementing ceramic restorations depends on the quality and durability of the bond,[15] which depends upon the bonding mechanisms that are controlled mainly by the surface treatment that enhances micromechanical and/or chemical bond to the substrate.[43] Other mechanisms also tested to enhance the micromechanical retention are airborne particle abrasion and coarse diamond rotary instruments. Studies showed that airborne particle abrasion using alumina particles or silica-modified alumina particles resulted in a significant increase in the bonding to resin.[44,45] Additionally, the cementation surface of graded restorations can be etched with hydrofluoric acid and silanized to facilitate a resin–cement bond.

CONCLUSION

Zirconia crowns offer a promising alternative for prosthodontic restorations in premolar and molar regions. Good chemical and dimensional stability, along with mechanical strength and toughness, coupled with a Young's modulus in the same order of magnitude of stainless steel alloys was the origin of the interest in using zirconia as a ceramic biomaterial. No complications were found in 88% of the crowns over a 5-year period, and just 9% were judged as failures. Longer-term success rates remain to be determined. The graded glass–zirconia approach has addressed an important clinical problem in connection with zirconia-based restorations – susceptibility to chipping and fracture of the veneering porcelain. When compared with all other ceramic dental materials, zirconia Y-TZP possesses better mechanical properties due to its transformation toughening. However, the lack of long-term survival data makes it difficult to judge the properties of zirconia full crowns. The development of nanostructured zirconia can continue to improve the biomechanical properties. Further research is needed to explore the potential of zirconia as a substitute to the existing dental restorative material.

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