LITERATURE REVIEW

Zirconia: Substitute for Metal Ceramics

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ABSTRACT

In the search for the ultimate esthetic restorative material, many all-ceramic systems have been proposed. Dental research is nowadays directed toward metal-free prosthetic restorations in order to improve an esthetical outcome of crown and bridge restorations. Zirconia is a polycrystalline ceramic without a glassy phase and exists in several forms. Zirconia cores for fixed partial dentures (FPD) on anterior and posterior teeth and on implants are now available. This article is a review of zirconia crowns as replacement for conventional metal-ceramic crowns.

Keywords: Zirconia, Metal ceramic, Cosmetic dentistry, Esthetics, Mechanical properties.

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INTRODUCTION

Natural look of soft tissue in contact with fixed partial dentures (FPD) is influenced by two factors: mucosal thickness and typology of restorative material. Metal free restorations allow preserving soft tissue color more similar to the natural one than porcelain fused to metal restorations.

Meta-analyses have demonstrated good long term clinical results for the conventional fixed dental prosthesis (FDP) with a metal framework.[1-3] As dentistry has evolved, the demand for metal free materials with increased translucency (Figs 1 and 2) that mimic the natural dentition has arisen.[4]

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This has led to the development of several different ceramics that are esthetically pleasing and biocompatible.[5-7] What is still being established is which materials are acceptable not only for their favorable optical properties, but also for their favorable mechanical properties, adequate clinical function and longevity.

Zirconia (ZrO_2) is a ceramic material with adequate mechanical properties and is a crystalline dioxide of zirconium. Its mechanical properties are very similar to those of metals and its color is similar to tooth color.[8] In 1975, Garvie proposed a model to rationalize the good mechanical properties of Zirconia, by virtue of which it has been called 'ceramic steel'.[9]

Zirconia crystals can be organized in three different patterns: monoclinic (M), cubic (C) and tetragonal (T). By mixing zirconia (ZrO_2) with other metallic oxides, such as MgO, CaO, or Y_2O_3, great molecular stability can be obtained.[10] Yttrium-stabilized zirconia, also known as tetragonal zirconia polycrystal (TZP), is presently the most studied combination.[11] Zirconia stabilized with Y_2O_3 has the best properties for these applications.

When a stress occurs on a zirconia (ZrO_2) surface, a crystalline modification opposes the propagation of cracks. Its resistance to traction can be as high as 900 to 1200 MPa and its compression resistance is about 2000 MPa. Cyclical stresses are also tolerated well by this material. Applying an intermittent force of 28 kN to zirconia substrates, Cales found that some 50 billion cycles were necessary to break the samples, but with a force in excess of 90 kN structural failure of the samples occurred after just 15 cycles.[12] Surface treatments can modify the physical properties of zirconia. Exposure to wetness for an extended period of time can have a detrimental effect on its properties.[13] This phenomenon is known as zirconia ageing. Moreover, also surface grinding can reduce toughness.[14] Kosmac confirmed this observation and reported a lower mean strength and reliability of zirconium oxide after grinding.[15]

Basic Properties

The first proposal of the use of zirconium oxide for medical purposes was made in 1969 and concerned orthopedic application. Orthopedic research focused on the mechanical behavior of zirconia, on its wear, and on its integration with bone and muscle. Since 1990, *in vitro* studies

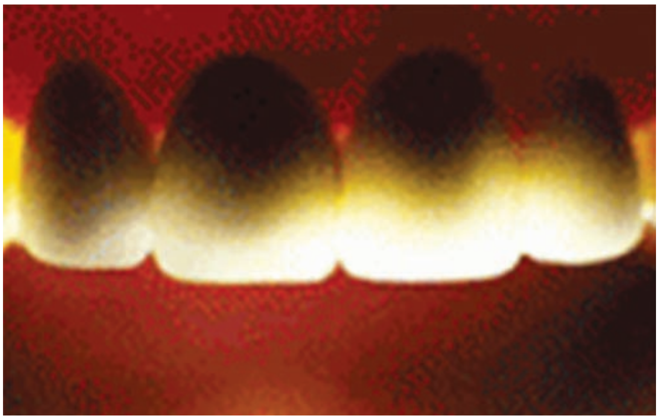

Fig. 1: Metal ceramic restorations

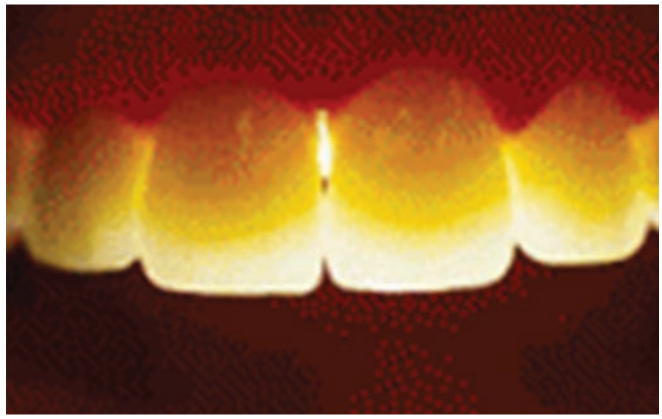

Fig. 2: Zirconium based restorations

have also been performed in order to obtain information about cellular behavior toward zirconia.[16] *In vitro* evaluation confirmed that zirconia (ZrO_2) is not cytotoxic.[17-19] Zirconium oxide creates less flogistic reaction in tissue than other restorative materials, such as titanium.[20] This result was also confirmed by a study about peri-implant soft tissue around zirconia healing caps in comparison with that around titanium ones.[21] Inflammatory infiltrate, microvessel density, and vascular endothelial growth factor expression was found to be higher around the titanium caps than around the zirconia (ZrO_2) ones. Also, the level of bacterial products, measured with nitric oxide synthase, was higher on titanium than on zirconium oxide. Zirconia can up- or down-regulate expressions of some genes, so that zirconia can be regarded as a self-regulatory material that can modify turnover of the extracellular matrix.[22]

Clinical Applications

Raigrodski analyzed different all-ceramic systems and concluded that reinforced ceramics can only be used to replace anterior teeth with single crown restorations or maximum with three units FPD. On the other hand, zirconia (ZrO_2) restorations have a wider application field. Other ceramic technologies only allow the construction of structures that are resistant to chewing stresses on anterior teeth. On the contrary, zirconia-ceramic FPD can also be used on molars.[23]

Tinschert compared lifetime of different metal-free core for FPD and reported that zirconia-ceramic with alumina oxide had the highest initial and most favorable long-term strength.[24] Connecting surface area of the FPD must be at least 6.25 mm^2.[25] For this reason, ceramic FPD should only be used when the distance between the interproximal papilla and the marginal ridge is close to 4 mm. In a comparison between 3, 4 and 5 unit zirconia FPD and minimal connecting surface resulted, respectively, 2.7 mm^2, 4.0 mm^2 and 4.9 mm^2.[26] Height of abutment is fundamental to obtain zirconia (ZrO_2) frameworks with correct shape and dimension in order to ensure mechanical resistance of restoration. This aspect must be carefully considered when realizing a metal-free FPD.

Zirconia restorations have found their indications for FPD supported by teeth or implants. Single tooth restorations and FPD with a single pontic element are possible on both anterior and posterior elements because of the mechanical reliability of this material.[27-29] It is possible to use juxtagingival marginal preparations and various

Fig. 3: Prepared discolored non-vital teeth

Fig. 4: Cemented zirconia-ceramic crowns

finishing lines to obtain a good esthetic (Figs 3 and 4).[30] Fixed partial denture extension is nowadays a limitation in using zirconia-ceramic restorations. Although some manufacturer allows obtaining also full arch restorations, five units FPD are reported to be as maximal possible.[31]

Zirconia opacity is very useful in adverse clinical situations, for example, for masking of dischromic abutment teeth.

Radiopacity can aid evaluation during radiographic controls. Zirconia frameworks are realized by using computer-aided design/manufacturing (CAD/CAM) technology. As the development of zirconia crown using CAD/CAM technology, the usage of full zirconia crown is gradually increased.

When compared to the layering technique which is fabricated with zirconia coping and veneering porcelain, full zirconia crown shows higher strength and easier laboratory procedure. To prevent mechanical fracture of the full zirconia crown, the thickness of zirconia crown and proper sintering process should be considered.[32] Nearly all (87.5%) conventionally veneered crowns failed already during chewing simulation, whereas crowns with CAD/CAM manufactured veneers were nonsensitive to artificial ageing. Crowns veneered with lithium disilicate ceramic displayed ultimate loads to failure of about 1600 N.[33]

Although many types of zirconia-containing ceramic systems are currently available only three are used to date in dentistry. These are yttrium cation-doped tetragonal zirconia polycrystals (3Y-TZP), magnesium cation-doped partially stabilized zirconia (Mg-PSZ) and zirconia-toughened alumina (ZTA).[34]

CONCLUSION

Although clinical long-term evaluations are a critical requirement to conclude that zirconia has good reliability for dental use, biological, mechanical, and clinical studies published to date seem to indicate that zirconia (ZrO_2) restorations are both well tolerated and sufficiently resistant. Ceramic bonding, luting procedures, ageing and wear of zirconia abutment should be evaluated in order to guide the adequate use of zirconia as prosthetic restorative material. Patient selection, coupled with adequate clinical and technical protocols, are imperative in order to obtain good performance of these restorations. The CAD/CAM production of veneers for restorations with zirconia framework is a promising way to reduce failures originating from material fatigue.

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