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Translucent Zirconia- A Step towards Esthetics- A Narrative Review

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ABSTRACT: Zirconia is widely used as a dental biomaterial in recent years. As zirconia undergoes a transformation toughening mechanism dental zirconia shows increased fracture toughness and bend strength. The disadvantage of zirconia was its opaque appearance resulting in compromised esthetics. To overcome the poor translucency and grayish-white appearance a new translucent zirconia is introduced. New translucent zirconia has been developed to match the strength with improved esthetics. This article aims to review the optical and the Magical properties of the newly developed translucent zirconia.

KEYWORDS: Color, Esthetics, Translucent, Zirconia.

INTRODUCTION

Over recent years, the demand for esthetics and tooth tooth-colored by the dental patients have increased [1]. The natural appearance of the teeth is difficult to achieve by dental restoration due to its complex optical properties [2]. Selection of the material, form, surface texture, translucency, and color are the factors that are taken into consideration for achieving natural-looking dental restoration. There is the selective transmission of specific wavelengths from the natural enamel and dentin due to back-scattering and forward-scattering light. The small, polycrystalline, aligned hydroxyapatite crystals are responsible for the bluish-white color of the enamel as they scatter shorter wavelengths. The organic component, ultraviolet-photosensitive, and fluorescence of the dentin counteract its orange color. Not a single dental ceramic is able to replicate this complex behavior of light and the optical properties of natural dental tissues.

Metal ceramic restorations were widely used used in dentistry over the past few years due to their increased strength and long-term longevity. The esthetic appearance of these restorations is influenced by the alloy used (base, noble or high noble) and its color (yellow or gray**)** [3] however also by the thickness, color and intrinsic translucency of layering ceramics. As the esthetic demands of dental patients increased immensely, a variety of all ceramic systems are introduced into the market [1,2]. Ceramic materials are classified into three categories based on their chemical composition into glass matrix ceramics, polycrystalline ceramics, and resin matrix ceramics. Glass ceramics (feldspathic, leucite-reinforced glass ceramics, lithium disilicate glass ceramics) are composed of a glass matrix containing dispersed crystalline minerals (feldspar, silica, alumina) [5,6]. These systems are recommended for esthetic restorations due to their increased translucency. However, these systems have limited capacities to conceal a discolored abutment [7]. Their mechanical properties are lowered as compared to other ceramics. Polycrystalline ceramics are oxide ceramics. Here the particles are densely packed with the absence of a glassy phase, this material are considered as the toughest ceramics used in dentistry. Resin-matrix ceramics are dental ceramics composed of an organic matrix combined with ceramic fillers. Hybrid ceramic is a new category of restorative material, with a dual structure: the ceramic network structure is reinforced with a polymer network structure[31].

Zirconia is one of the tooth color material. Zirconia shows good esthetic characteristics and exhibit sufficient mechanical strength and toughness. Zirconia is a material that can exist in three crystalline phases: tetragonal, monoclinic and cubic[15]. Pure zirconia has a cubic structure at temperatures above 2,370 ºC, [16,17] with the crystals in the form of a cube with square sides and possesses moderate mechanical properties . The tetragonal phase occurs at temperatures between 1,170 ºC and 2,370 ºC, [17,18] crystals have the form of straight prisms with rectangular sides, having the best mechanical properties. The monoclinic phase occurs at room temperatures to 1,170ºC, [16] has a deformed parallelepiped shape and possesses the weakest mechanical properties. Zirconia undergoes a tetragonal to monoclinic phase transformation when cooling down from high temperatures after sintering, which makes the sintered material unstable. [20] This results in a 3% to 5% expansion in the grains volume, [21] which result in surface roughening, micro-cracking and deterioration of the mechanical characteristics. Various types of zirconia are available for dental applications, including partially stabilized zirconia (PSZ), tetragonal zirconia polycrystal (TZP), zirconia toughened alumina (ZTA) and fully cubic stabilized zirconia (CSZ) [41-44]. Conventional zirconia has excellent strength, but poor translucency. Dental manufacturers tried to satisfy the interest for higher esthetic monolithic zirconia ceramics by creating unique formulations of this restorative material [44]. As a result, new translucent variants of zirconia have been developed with improved optical properties,

METHODS OF MAKING THE ZIRCONIA TRANSLUCENT

It is claimed that the opaque appearance of the zirconia is due to the grain size(approx. 0.4) of the dental zirconia compared to the wavelength of the light, different phases (monoclinic, cubic, tetragonal) with different refractive indices, mismatch of the refractive indices between the grain particles and size[35,36]. All these factors are responsible for the scattering of the light rather than transmitting through the material giving it an opaque appearance[37].

To overcome this optical deficiency of opaque zirconia many methods have been made. The basic aim is the alteration of the grain size and matching the refractive index of the crystalline and the matrix phase [37].

Reducing the grain size was the first method of increasing the translucency of the zirconia. High in-line transmission will result in more translucency. According to the study it was found that, for 1.3 mm thickness, 82nm grain size will achieve translucency similar to that of dental feldspatic porcelain. In another study conducted it was found that, for 1.5mm and 2mm thickness ceramic the translucency was achieved by attaining the grain size of 77 and 70nm respectively. The major disadvantage with decreasing the grain size was the alteration in the mechanical properties of the material. Decreasing the grain size affect the strength of the material. [38-45].

Another way to increase the transparency of zirconia is to increase the concentration of the yttria impurity, which results in a greater amount of the cubic phase. A typical 3Y-TZP consists of 5.18 weight percent yttrium (3 mole percent yttrium) and 90% or more tetragonal zirconium. The cubic phase and transparency increase with increasing yttrium content. 3M ESPE presented an experimental translucent zirconia (Abstract #796) containing 7.10 wt% yttria-stabilized zirconia powder at the 201 AADR Annual Meeting in Charlotte, NC. The resulting material contained 75% tetragonal zirconia and 25% cubic zirconia with an average grain size of 150 nm. The combination of increasing the amount of cubic phase and decreasing the grain size made the test material more transparent. Tosoh Corporation used the same approach to produce Zpex Smile, a new translucent zirconia. In this material, a higher concentration of yttrium (9.32 wt%, corresponding to 5 mol% yttrium) was used to increase the content of the cubic phase. As the tetragonal phase decreases and the number of cubic crystals increases, the LTD effect may decrease; However, it has been reported that due to the range of transformation stress, the bending strength and fracture strength are reduced by half to two thirds of those of partially stabilized tetragonal zirconia. As a general theoretical approach, 8% yttria content leads to complete stabilization of cubic zirconia, and -5% yttria content (Y-PSZ, 5YPSZ) leads to partially stabilized cubic zirconia with 50% cubic phase content. 8% soft yttria has been marketed as ultraclear zirconia (Prettau Anterior (Zirkonzahn), DD cube X2 (Dental Direkt), Katana Zirconia St and Katana Zirconia Ut Noritake (Kuraray Noritake Dental)). 5% mol is specified as ultra clear zirconium (Prettau (Zirkonzahn), BruxZir (Glidewell), Zenostar (Ivoclar Vivadent), Katana Ht and Katana ML Noritake (Kuraray Noritake Dental) [50-52].

Reducing the impurities is the third method to increase zirconia translucency. Ceramics are optically nonhomogeneous materials. Grain sizes ranging between 200-400 nm having less than 0.05 impurities will significantly reduce translucency in zirconia specimens. Alumina stabilizes the tetragonal zirconia and also involved in reducing the pores formation in zirconia. Alumina is added as a sintering aid. Impurities such as alumina sintering additives, reduces the translucency of Y-TZP The size and amount of impurity content will affect zirconia translucency by 50%. Therefore, developments of reduced alumina content zirconia ceramics led to more translucent zirconia (BruxZir (Glidewell) and Lava™ Plus (3M ESPE)); however, this reduction may accelerate the LTD phenomenon [54-55].

The fourth successful method to improve translucency was increasing the content of lanthanum oxide to 0.2% mol.

PROPERTIES OF TRANSLUCENT ZIRCONIA

Variations in the properties of new translucent zirconia than the earlier zirconia is due to the change in the molecular structure.

Strength

According to the study done by LanTH, Liu PH the flexural strength of the translucent zirconia is half of the conventional zirconia and three times more than that of the veneering material. The flexural strength of the core material crowns which are layered with

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conventional porcelain is less than the overall strength of the crown restoration fabricated from the monolithic translucent zirconia. Its flexural strength is two third greater than the lithium disilicate.

Johnsson C. et al. 2014 conducted the study to measure the fracture strength of the translucent zirconia with the porcelain veneer crowns and the lithium disilicate crowns. The study concluded that the fracture strength of the translucent zirconia crowns are higher than the porcelain veneered and lithium disilicate crowns [22].

Nakamura K. et ak. 2015 conducted a study to measure the fracture resistance of translucent zirconia. The study inferred that translucent zirconia crown with chamfer width minimum thickness 0.5mm can be used in the molar region in terms of fracture resistance[67].

Zhang Y. et al 2016 conducted a study to determine the fracture load between translucent zirconia, lithium disilicate and nano-composite. This study interpretated that the fracture load of translucent zirconia was highest than for lithium disilicate was intermediate and for nano-composite it was lowest[69].

Matsuzaki F et al. 2015 evaluated the flexural strength of the translucent zirconia by biaxial bending test and this study concluded that the translucent zirconia showed approximately 1000Mpa[68].

Translucency and color

The opaque appearance of the zirconia was the major disadvantage of zirconia crowns. Material structure, cement layer, restoration thickness and LTD phenomenon determine the appearance of the restoration. Translucency depends on the grain size, impurities, and yttria content. In ceramics, the study shows correlation between translucency and thickness but in zirconia translucency is not dependent on the thickness.

The translucency parameter(TP) for enamel is 16.4 and for dentin it is 18.7[86]and for different types of translucent zirconia, it is between 11.2 to 15.3[3].

Matsuzaki F et al. 2015 evaluated the translucency parameter by colorimeter and concluded that translucent zirconia improves the translucency[68].

Wang F et al. 2013 also evaluated the translucency by spectropolarimeter and concluded that the translucency is affected by the brand and thickness[79].

Harianwala H H et al. 2014 studied transmittance value by dual beam UV spectrophotometer and inferred that high translucent zirconia is more translucent than conventional zirconia[34].

Low Temperature Degradation (LTD)

In warm environment (<500) transformation from the tetragonal phase to monoclinic phase takes place which results in the aging of the zirconia firstly over the surface then gradually increasing the depth and finally altering the bulk properties of the material. This phenomenon is known as low temperature degradation. This will lead to roughening, formation of microcracks and reduction in the fracture load.

Although LTD is seen between 200-400C, long exposure of material to moist and heat in the oral cavity may also result in LTD. Factors such as grain size, alumina content, yttria and silica content determines the property of resistance of zirconia to LTD. To prevent LTD alumina content should be greater than 0.15 wt% but to reduce the impurities so as to increase the translucency the alumina content is reduced which in the end increases the susceptibility of the material towards the LTD. Studies showed that even after aging of the translucent zirconia it has maintained sufficient strength[49].

Abrasion and wear properties

Comparing the antagonist wear properties, studies have shown that the polished monolithic zirconia are less abrasives than the veneering ceramics or lithium disilicate. Various studied have been done over the same.

Stober T. et al. 2014 measured enamel wear by plaster replicas and 3d laser and found out that the antagonist enamel wear of monolithic zirconia was leass as compared to other ceramic materials after 6 months[15].

Stawarczyk B. et al.2013 measure the two body wear characteristics of zirconia and enamel antagonist with a 3d profilometer and under scanning electron microscopy and the study concluded that polished monolithic zirconia showed lower wear rate on enamel antagonists as well as within the material[24].

Hara M. et al.2014 measured the wear performance of tooth enamel against translucent zirconia and feldspar porcelain. This study inferred that wear of tooth enamel against translucent zirconia was less as compared to feldspathic porcelain[88].

Abutment Preparation

All ceramic restorations have an optimal aesthetic appearance when tooth preparation is accurately performed. This involves a minimally invasive preparation, with the highest preservation of the remaining natural dental structure. For conventional all-ceramic restorations, the tooth reduction for the occlusal clearance would be 2mm and for proximal and axial clearance 1.5mm . However, for the cubic monolithic zirconia restorations a clearance of 0.5-1mm is needed, according to a specific clinical situation. The finish line design for a monolithic zirconia restorations is rounded shoulder or light chamfer of 0.5mm width. The framework design has a great influence on fracture resistance of a translucent monolithic zirconia bridge. Therefore, to obtain the same resistance to fracture, the connector area of two translucent zirconia crowns should measure 9 mm, compared to the connector area of lithium disilicate restorations of 16 mm[16].

Polishing and glazing

If occlusal adjustment is required after delivery, the restoration can be polished with a diamond-impregnated silicone instrument and polishing paste containing up to 20% diamond particles with a grain size of 2- µm and a maximum rotation speed of 15,000 rpm. to maximize the brightness of the final restoration. However, it is strongly recommended to correct the surface shape before sintering to achieve a more natural shape and avoid micro-roughness. To adjust the bite, it is recommended to use a special diamond grinder (eg ZR grinding machine, Komet, Gebr. Brasseler or K-Diamonds, Edenta) under water cooling[90].

Cementation of monolithic zirconia restorations

Resin cement are the most used dental materials for cementation of full ceramic restorations because they have good esthetics, low solubility, high strength, and mechanical resistance. Dual-cure resin cement with phosphate or carboxylate groups is the best choice for bonding zirconia restorations. To increase the bond strength, the zirconia crowns are sandblasted, usually with oxide aluminum particles[64].

CONCLUSIONS

Within the limitations of this study, a review of the literature showed that several factors can influence the properties of a restoration made of translucent zirconia, leading to the following conclusions: The molecular structure and physical properties of translucent zirconia differ from conventional zirconia; it shows reduced strength and stress tolerance. Factors such as grain and pore size and crystal configuration affect optical and mechanical properties. This material has mechanical and aesthetic properties between conventional zirconia and lithium disilicate. Pre-shaded and multi-layered translucent zirconia blocks offer mechanical properties and good aesthetics suitable for the restoration of individual anterior teeth as well as for the construction of whole-mouth rehabilitation. Polished translucent zirconia fillings consume less antagonistic tooth structure than glazed or other ceramic materials. The aesthetic appearance of the clear zirconia piece can be affected by the colored background and bonding cement. The thickness of the clear zirconia and the shade and transparency of the cement have a significant effect on the final color of the restoration.

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