Factors affecting the translucency of monolithic zirconia ceramics: A review from materials science perspective

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Clinical factors affecting the translucency of monolithic Y-TZP ceramics

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ABSTRACT

The use of monolithic yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) ceramics in aesthetically critical regions is questionable because of the insufficient translucency and opacity of the restorations. Intrinsic (manufacturing process) and extrinsic factors (laboratory procedures and clinical factors) can affect the translucency of monolithic zirconia. In this narrative review, the clinical factors (thickness, cementation type, colour of the monolithic zirconia, surface finishing methods and wear, dental background, cement colour, low temperature degradation) affecting the translucency of monolithic Y-TZP ceramics was reported.

Keywords*:* Zirconia; Monolithic; Translucency; Colour; Wear

1. Introduction

In recent years monolithic yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) restorations have been produced to eradicate the risk of veneering porcelain chipping or fracture [1]. They have become popular due to their high flexural and mechanical strength, minimal wear on opposing teeth, shortened time of fabrication (clinical and laboratory), no need of veneering porcelain, decreased cost [1-6], and allowing production of prostheses with significantly reduced thickness such as 0.5 mm [7-9]. The other clinical advantage of full contour monolithic zirconia restorations is that of alternatively they can be used either in a hybrid design such as the buccal and lingual aspect of the monolithic restoration can also be veneered to enhance an aesthetic outcome [10].

Monolithic Y-TZP restorations are fabricated from computer aided design/computer aided manufacturing (CAD/CAM) using either partially or fully sintered blocks [11]. They can be finished either polishing or glazing [12].

Colour and translucency are two factors affecting the aesthetics of all-ceramic restorations, which the latter is of primary importance in aesthetics [13]. It is related to the transmission and adsorption of light. In a dental restoration, if only a minor part of the light is scattered and most is transmitted diffusely, the material will appear translucent [14].

In prosthetic dentistry in order to achieve aesthetic appearance, the optical behavior of a translucent monolithic Y-TZP needs to be similar to that of the natural tooth [15]. It was reported that intrinsic (material microstructural and processing properties) and extrinsic factors (laboratory and clinical factors) can affect the translucency of monolithic zirconia restoration [16]. Although intrinsic parameters can not be manipulated by the clinician, extrinsic factors can be manipulated by the clinician. Clinical parameters, such as thickness [10,14,17-21], cementation type [22], colour of Y-TZP ceramics [5,17,19,23-28], surface finishing protocols [14,29,30], the use of Y-TZP ceramics as implant abutments [31-34], dental background [35-38], cement colour [39,40], and low temperature degradation [10,41-46] which are in the category of extrinsic factors should also be taken into consideration when evaluating the translucency of monolithic Y-TZP ceramics. This narrative review gives knowledge about the clinical factors that affect the translucency of monolithic Y-TZP ceramics which can be effective in clinical success of these ceramics.

2. Clinical factors affecting the success of monolithic Y-TZP ceramics

2.1. Thickness

Thickness of monolithic Y-TZP ceramics is important for the amount of light passing through the restoration [47]. In the literature, the effect of different thicknesses on the optical properties of monolithic zirconia ceramics [10,14,17-21], and multilayered monolithic zirconia [48] were evaluated. All of these studies [10,14,17-21,48] outlined that thickness inversely affected the zirconia translucency data. Therefore, based on the results of these studies [10,14,17-21,40,48,49], the restorations with the monolithic Y-TZP ceramics can be thinner as 0.5-0.9 mm taking into account that not compromising the strength and color of the material. In addition, making the restorations thinner in order to create more translucent restoration should be done with attention, because the masking ability of the zirconia of coloured teeth should also be taken into account and the thickness balance should be considered according to the specific case.

2.2. Cementation type

Cementation of monolithic Y-TZP ceramic restorations can be done with traditional cements (glass ionomers, phosphate or polycarboxylate cements) or resin cements [50]. It was reported that [22] cementation type affected the translucency of monolithic zirconia restorations and resin cements/resin modified glass-ionomer cements presented higher translucency values than conventional glass-ionomer cements.

2.3. Colour of the monolithic Y-TZP ceramics

The clinical colour matching with the tooth restored or the neighboring teeth using monolithic Y-TZP ceramics is challenging. To overcome this issue, manufacturers have produced preshaded monolithic zirconia ceramics, externally shaded monolithic zirconia, or multilayered monolithic zirconia ceramics with different translucency levels such as high, super, and ultra translucency [38].

Preshaded zirconia blanks are manufactured adding colourant pigments (metal oxides) (Fe_2O_3, CeO_2, and Bi_2O_3) to zirconia powder through manufacturing process [26]. They are mostly available according to VITA classical shades [38].

Externally shaded zirconia can be obtained by immersing non-sintered or pre-sintered uncoloured zirconia in colour liquids [26], or using colour liners over sintered zirconia [26,51]. In immersion technique, type and shade of colour liquid, and the dipping time should be considered [52]. Manufacturers have also generated different shades (VITA classical or VITA 3-D Master) for colour liquids [26,53].

Recently, highly translucent multi-layered monolithic zirconia ceramics have been proposed as a solution for the colour improvement of monolithic zirconia restorations [28,54,55]. They have derived from the concept of production of zirconia blocks containing different layers with various translucencies and shades. Ueda et al. [28] investigated the light transmittance of different layers of these material and found significantly different light transmission mean values among four layers.

It was reported that colouring may influence the optical property of zirconia by producing crystallographic and microstructural alterations in the material [5,26]. Suleiman et al. [5] examined the effects of external staining on translucency parameter data of fully stabilized zirconia versus partially stabilized zirconia and stated a significant decline in the translucency of fully stabilized zirconia after staining. They based this finding to the larger grains and grain boundaries of fully stabilized zirconia that may have led to an increase in colouring liquid intake, therefore resulting in reduced translucency. On the other hand, Kurtulmuş-Yılmaz et al. 2014 [24] reported that external colouring technique did not have a significant effect on translucency of zirconia cores. Sen et al. [25] indicated that translucency of monolithic zirconia was impressed by material type, however not affected by the colouring technique (pre or ext). Some studies [17,27] reported that for the same zirconia material, shading technique (ext or pre) affected the translucency of monolithic zirconia. Alp et al. [17] reported that at thickness of 1, 1,5 and 2 mm, and Subasi et al. [27] reported that at a thickness of 1,5 mm externally shaded zirconia showed significantly higher translucency value than preshaded monolithic zirconia. Other studies [24,56] reported significant differences among the translucencies of differently pre-shaded monolithic zirconia materials.

To sum up, all of these studies [5,17,24-27,56] results showed that translucency of zirconia is dependent on the material type. Therefore, in clinical practice to obtain better translucency the selection of shading technique (external or preshaded) is dependent on the selection of the zirconia type.

2.4. Surface finishing methods and Wear

Before delivering the restoration to the patient, final surface state of monolithic Y-TZP ceramics is of great importance, because it might affect the translucency, tribological, and metastability behavior of the material. The manufacturers of monolithic zirconia recommend either polish or glaze treatments for final surface finishing of these restorations before the cementation of the restoration to the patient's tooth. Therefore, these surface treatments effect on translucency should be considered.

Studies [14,29,30] declared no differences in translucency between polished and unpolished monolithic zirconia ceramic surfaces. In addition, Kim et al. [30] reported that there was no difference in translucency parameter data between polished and glazed of externally shaded monolithic zirconia, while glazing reduced opalescence.

Surface treatments may have an impact on tribological behaviors. Some studies [9,57-60] reported that against enamel, polished monolithic zirconia presented less wear than glazed monolithic zirconia. In addition, Zurek et al. [61] reported that against ceramic, glazed-polished monolithic zirconia surface presented lower volume loss than monolithic glazed zirconia surface. Based on these studies results [9,57-61], the glaze layer over the Y-TZP restorations may be worn in time and the restoration would come to contact with the opposing tooth or restoration. Therefore, in this situatation the surface state of the monolithic Y-TZP ceramic becomes more important for metastability of the material.

Surface treatments or wear can also affect the metastability property (phase transformation) of monolithic Y-TZP. Before cementation the restoration inner surface can be adjusted with burs or can be air abraded before adhesive cementation [62,63]. It is well known that, the grinding and sandblasting of zirconia materials lead to surface phase transformation (tetragonal to monoclinic), and development of compressive stresses [9]. Chair-side polishing eliminates this thin monoclinic phase to a certain degree but deep defects and scratches that are created with coarse burs may remain on the restoration surface. Furthermore, after polishing, surface stress state of the material would lead to sensitivity to low temperature degradation (LTD) by enhancing monoclinic phase nucleation around residual scratches [64]. Therefore, it is of great importance to carefully polishing the surface of monolithic Y-TZP restoration if grinding adjustments are made in the laboratory or before delivering the restoration to the patient. On the other side, heat treatment or final glaze firing following grinding and sandblasting was pointed out to reverse the phase transformation (monoclinic to tetragonal) and eradicate compressive stresses [64,65]. Therefore, in clinical practice, after adjustements in the laboratory, the restorations can be fired as reported by previous studies [64,65].

2.5. The use of monolithic Y-TZP ceramics on implants

Monolithic Y-TZP ceramics are also used in fabrication of implant abutments as single- or multi-unit cemented restorations. However, it is not preferred due to limited fracture strength of the monolithic Y-TZP material. The main problems are associated with design and processing with custom CAD/CAM abutments. Microcracking after machining and cubic phase at abutment

surfaces cause failures of the monolithic Y-TZP ceramic restorations [1]. Therefore, titanium based hybrid abutments are used instead of using monolithic material.

In case of implant abutments, translucency of the material is the issue, because the material thickness has to be much more than the tooth supported restorations. Furthermore, the translucency of the restoration may be affected from the abutment type (titanium or zirconia) [31-34].

2.6. Dental Background

In a dental restoration, a background (enamel or dentin) is the deepest layer that light may undergo. The background condition is based on the translucency of ceramics. As the ceramic translucency increases, the background effect increases [66].

Monolithic zirconia ceramics are more translucent than framework zirconia ceramics and less translucent than feldspathic and glass ceramics [18,20,21,47,67]. Considering the background condition, most of the manufacturers have manufactured zirconia ceramic brands with different levels of masking ability on coloured backgrounds (light, medium, dark shaded, metal) [38].

In clinical practice, to compensate for the background condition, several solutions are recommended: such as using backgrounds with colour close to main colour [36,37], masking backgrounds with proper cements [35], or rising the zirconia thickness [37,39,40,68].

2.7. Cement Colour

Regarding optical characteristics, cements are classified into shaded, bleached, opaque, and transparent [69,70]. Opaque cements create a lighter shade, while transparent cements create a darker shade [71]. If the cement is more transparent, the background effect becomes more critical [35]. If the ceramic restoration is more translucent, the cement becomes more critical [72].

Opaque cements may be used for dark/metal/discoloured backgrounds to mask them, but then an increase in ceramic thickness is needed to compensate for the cement colour. In addition, tooth-coloured cements may be the choice for tooth-coloured backgrounds to create colour consistency between cement, background, and ceramic according to target colour. This fact profitably eradicates the need for increasing the ceramic thickness [38].

Depending on the cement and background conditions, the minimum zirconia thickness may be in the range of 0.9-1.6 mm [39]. When tooth-coloured backgrounds and cements are used, zirconia thickness may be declined to the minimum such as 0.5 mm. When discoloured/metal backgrounds and opaque cements are preferred, zirconia thickness should be increased. Finally, a background-cement-ceramic colour consistency is recommended to increase the translucency of monolithic zirconia restorations [39,40].

2.8. Low Temperature Degradation (LTD)

LTD is another important factor that affects the clinical success of monolithic zirconia restorations. LTD is a phenomenon that existence of water and low temperature over time, a tetragonal-monoclinic (t-m) phase transformation is provoked at zirconia ceramic surface [73]. This ends in a volume enlargement of grains, which causes surface roughening, microcracking, and possibly loss of strength. Regarding different monolithic zirconia ceramics, studies [41,43-46] showed that translucency is affected by the

aging process. Some of them [41,43,45,46] reported that translucency was material dependent and decreased after aging. On the other hand Kim et al. [44] reported an increase in translucency after aging.

The optical properties of monolithic zirconia materials are influenced by their microstructure. Due to aging or mechanical stress crystal structure of monolithic Y-TZP may alter from tetragonal to monoclinic [74,75]. Monoclinic and tetragonal crystals have distinct optical properties [76], and monoclinic zirconia crystals scatter light more than other crystals [77]. Therefore, change in translucency after aging is associated with transformation of zirconia from tetragonal to monoclinic phase [43-45].

Harada et al. [10] reported that the reduction of transformation from tetragonal to monoclinic phase after aging may be produced by using translucent zirconia that contains reduced Al_2O_3 content to develop light transmittance and a raise in Y_2O_3 content to decrease LTD. Therefore, in clinical practice to minimize the effect of LTD, material selection of monolithic zirconia is important.

In recent years, partially cubic monolithic high translucency or multi-layered zirconia was manufactured [42]. Camposilvan et al. [42] reported that these materials may be more translucent than standard 3Y-TZP and do not affect from in vitro hydrothermal degradation, however their toughness and strength are effectively lower. Thus, manipulation and crown preparation should be done carefully, and thin walls and sharp edges should be avoided as much as possible. In addition, they could not be used in the mouth where high mechanical stresses are exist.

3. Conclusions

The translucency of the monolithic zirconia is a complex phenomenon because different parameters such as intrinsic (manufacturing process) and extrinsic factors (laboratory procedures and clinical factors) affect its translucency. Within all of these factors, clinical factors (thickness, cementation type, colour of monolithic Y-TZP, surface finishing methods, the use of monolithic Y-TZP ceramics as implant abutments, background colour, cementation colour, LTD) can be controlled by dentists in clinical practice. Because of each clinical factor affects the other factor, to obtain clinical success in performing translucency of monolithic zirconia, all of these parameters should be evaluated together.

Clinical Relevance

In clinical practice to obtain pleasing aesthetics regarding translucency, clinicians should firstly select the monolithic zirconia type depending on the case. Other clinical factors such as cementation type, background colour, cement colour and thickness should be evaluated together depending on the selection of the monolithic zirconia type. In addition to lower the effect of LTD, final surface finishing of monolithic zirconia should be performed carefully to minimize the phase transformation.

Acknowledgements

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Conflict of interest

The authors did not have any commercial interest in any of the materials used in this study.

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