A Review on Translucent Zirconia

ABSTRACT

Introduction: Zirconia is suggested in many clinical situations due to acceptable biocompatibility, lower price compared with gold restorations, and better appearance than traditional metal ceramic restorations. New translucent monolithic zirconia has been developed to merge strength with improved tooth-colour matching. This work aims to review relevant articles on new translucent zirconia restorative materials. Methods: The published articles on translucent zirconia were searched through PubMed, Medline, Google scholar, and indexed journals using the following keywords: translucent zirconia, transparent zirconia, and tooth colored zirconia. The most relevant articles were selected and reviewed. Result: Introduction of translucent zirconia, has brought the advantages such as less tooth preparation, biological compatibility, high strength, good mechanical properties, and less antagonist wear. However, the effects of altering material constituents to increase translucency on properties such as phase transformation and low temperature degradation may warrant further investigations. Conclusion: Translucent zirconia can be prescribed in many clinical situations and may provide less complicated procedures compared with the production of multilayer restorations of opaque zirconia cores and translucent feldspathic veneers. This may otherwise decrease fabrication time and defects, improve biological properties, reduce abutment tooth reduction, and result in less antagonist tooth attrition.

Keywords

Translucent Zirconia
Translucency
Transformation Toughening
Low-Temperature Degradation
Grain Size
Yttria-Tetragonal Zirconia

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INTRODUCTION

Nowadays patients' trend toward esthetic and tooth-coloured dentistry have increased.

Zirconia is one of the tooth colored materials with several advantages including good esthetic characteristics, and excellent mechanical and biological behaviors that provide numerous indications in various clinical situations. Moreover, its lower price compared with precious alloy has led to extensive application in restorative dental treatments.[1-4] As the opaque appearance of zirconia negatively affects the esthetic outcomes,[5] layering materials were proposed to mask this appearance. However, porcelain chipping has been reported to be one of the most prevalent technical problems in veneered zirconia crown with annual rates ranging from 0 to 54%.[6] This phenomenon happens as adhesive failure (due to the weak link between core and veneering porcelain), or cohesive failure (a fracture within veneering porcelain body).[7-12] Even modifying the veneering technique and application of sintering procedure[13] or layering with CAD-CAM technology[14] did not completely solve this problem.[15] Porcelain chipping mostly occurs in the molar region and often necessitates some correction or even replacing the existing restoration for esthetic and functional demands.[16] Poor framework design, insufficient porcelain to zirconia bond strength, lower thermal conductivity and elastic modulus of zirconia compared with porcelain veneer[9,17-21] and some preparation errors are among the contributing factors.[6]

The suggested solutions to reduce porcelain chipping in esthetic all ceramic restorations are as follows: using CAD-CAM technology for designing core structure and applying veneering lithium-disilicate by a low-melting ceramic as an adhesive, modifying the cooling process during application of the veneering material,[16] and making fully contoured restoration using monolithic lithium-silicate or zirconia material[22-28] which have been the optional material for restoring single anterior and posterior restorations.[29]

Monolithic lithium-disilicate has several advantages over conventional multilayer restorations.[30] However, in high stress situations like multiunit posterior restoration in patient with parafunctional habit, it is necessary to use higher strength restorations.[3,31,32] In such a situation, yttrium-tetragonal zirconia polycrystalline (Y-TZP) zirconia can be the restoration of choice[3] but, the translucency of conventional Y-TZP is at most 70% of lithium-disilicate.[33] To overcome the problem of poor optical properties, translucent monolithic zirconia was introduced in 2011 as Cercon ht (Dentsply Intl, York, PA, USA) to make multiunit anterior monolithic FDPs without increased risk of porcelain fracture or reduced esthetic properties of the core material. In situation where the restoration should withstand higher stress, this material is claimed to combine good esthetic property with load bearing capacity.[34] The present article aims to review different characteristics of monolithic translucent zirconia.

MATERIALS AND METHODS

After searching the available articles on monolithic translucent zirconia through PubMed, Medline, Google scholar, and indexed journals, the articles which compare different aspects of monolithic translucent zirconia with other dental ceramic materials were included. Case report and non-peer reviewed articles were excluded. The applied keywords for search were translucent zirconia, transparent zirconia and tooth colored zirconia.

After evaluation and reviewing of existing articles, the information was categorized in following order:

1. Making zirconia translucent
2. Strength properties
3. Biological considerations
4. Color, translucency and esthetics
5. Abrasion and wear properties
6. Low temperature degradation (LTD)
7. Abutment preparation requirements
8. Glaze and adjustment
9. Surface treatment and cementation

RESULTS AND DISCUSSION

MAKING ZIRCONIA TRANSLUCENT

The opaque appearance of zirconia is claimed to result from the interaction of the typical grain size of dental zirconia (approximately 0.4 μm) compared with the wavelength of light (approximately 0.1-0.7 μm), the refractive index mismatch between grain particles and matrix, and the presence of monoclinic, cubic, and tetragonal phases also with different refractive indices.[35,36] These factors cause the light to be scattered rather than transmitting thorough the material and are responsible for the opaque appearance.[37]

In order to solve the optical deficiency in more opaque zirconia, many endeavors have been made with basic strategy of changing the crystal size and making the refractive index of crystalline and matrix phase closer to each other.[37]

The first method was increasing the grain size. It was shown that increasing the zirconia grain size, increases the contrast ratio.[38,39] Regarding the diffuse transmission mechanism, less scattering will happen as the result of less light encountering with grain-boundaries.[40] However, this dramatic change in the structure, reduces the strength of ceramic.[41,42] Moreover, spontaneous phase transformation from tetragonal to monolithic form –low temperature degradation (LTD)- happens when the grain size is above 1 μm.[43] With this mechanism, some success was achieved with introduction of translucent coarse-grained alumina (with 15-30 μm grain size that results in 90% translucency in 1mm thickness),[44] however, researches continued to find better methods for using zirconia as a translucent material in dentistry.[45]

The second approach to achieve more translucent zirconia, which appears to be more effective, is reducing the grain size.[46,47] High in-line transmission will result in more translucency.[40] Based on a study, for 1.3 mm thickness, 82 nm grain size will result in translucency near dental feldespatic porcelain. For 1.5 mm and 2 mm thickness ceramic, 77 nm and 70 nm grain size are suggested to achieve a more translucent material, respectively.[48] The challenging issue about the grain size concerns the material strength. Increasing and decreasing the grain size, both affect the strength of zirconia material. The grain size from 0.9 μm to 1.4 μm will increase the fracture strength linearly from 650 MPa to 1000 MPa. After the a critical grain size of 1.4 μm, the fracture strength will decrease to 750 MPa for a mean grain size of 1.8 μm.[49]

The third method is increasing the yttria dopant content, which leads to higher quantity of the cubic phase. The typical 3Y-TZP consist of 5.18 wt% yttria (3% mol yittria), and 90% or more tetragonal zirconia.[50] As yttria content increases, cubic phase and translucency increase. 3M ESPE presented an experimental translucent zirconia at the 2014 AADR Annual Meeting in Charlotte, NC (Abstract #796) which contained 7.10 wt% yttria-stabilized zirconia powder. The resultant material had

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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 reduction of grain size made the experimental material more translucent. Tosoh Corporation used the same approach to produce new translucent zirconia, Zpex Smile. In this material higher yttria concentration (9.32 wt.% equal to 5% mol yttria) was used to increase the cubic phase content. As tetragonal phase is reduced and cubic crystals increased, LTD effect may be decreased; however, due to a reduction in the extent of transformation toughening, flexural strength and fracture toughness has been reported to decrease by one-half to two-thirds of that of partially stabilized tetragonal zirconia. In a general theoretical approach, 8% mol yttria content will result in complete stabilization of cubic phase zirconia and 4-5% mol yttria content (4Y-PSZ, 5Y-PSZ) will result in partially stabilized cubic phase zirconia with 50% cubic phase content.[45] The 8% mol yittria content has been marketed as ultatranslucent zirconia (Prettau Anterior (Zirkonzahn), DD cube X2 (Dental Direkt), Katana Zirconia St and Katana Zirconia Ut Noritake (Kuraray Noritake Dental)). The 5% mol has been referred to as high-translucent zirconia (Prettau (Zirkonzahn), BruxZir (Glidewell), Zenostar (Ivoclar Vivadent), Katana Ht and Katana ML Noritake (Kuraray Noritake Dental)).[51] The grain size in 3Y-TZP and 4-5Y-PSP group is in range between 0.5 to 1 µm and the cubic phase zirconia group is approximately 1.5µm in order to increase translucency.[52] The denomination of different type of translucent zirconia with different construction method is still confusing and accurate classification is required in this field.

The fourth method to increase zirconia translucency is to reduce impurities. Ceramics are optically nonhomogeneous materials. Less than 0.05% impurity with grain sizes ranging between 200-400 nm will significantly reduce translucency in zirconia specimens.[45] Impurities such as alumina sintering additives, reduces the translucency of Y-TZP. Alumina is added as a sintering aid which minimizes pore formation in green-state zirconia throughout sintering. A further role of alumina contributes to tetragonal zirconia stabilization.[53] The size and amount of impurity content will affect zirconia translucency by 50%.[54] 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.[45] Another successful method to improve translucency was increasing the content of lanthanum oxide to 0.2% mol.[55]

Increasing the sintering temperature has been proposed as a method to increase translucency and an improved tooth-coloured restoration. Some manufacturers increase the final sintering temperature to improve translucency although flexural strength and stability of zirconia will decrease above 1550°C.[45] On the other hand, the presence of oxygen vacancy as a light scattering source, reduces the translucency.[56] Optimizing heat treatment to reduce oxygen vacancy and reduction of porosity at the same time has high importance.[45]

STRENGTH PROPERTIES

The strength of translucent zirconia is brand dependent.[22] It has been reported to be half of the conventional Y-TZP (with elastic modulus of 215 GPa and flexure strength of 1000 MPa), [57, 58] and 3 times more than the veneering material. Other studies showed similarity in fracture strength of this new product in comparison with the traditional opaque material.[59] The overall strength of crown restorations fabricated from monolithic translucent zirconia have been reported to exceed that of core material crowns which are layered with conventional porcelain.[22,23,31,60] The flexural strength of the material is claimed to be two thirds greater than that of lithium disilicate.[53,61,62] Fracture resistance of translucent zirconia is also higher than lithium disilicate[53,62] and porcelain-veneered restoration.[62] A clinical trial which evaluated the 5-year clinical performance of single and multiunit semitranslucent zirconia from 3 different manufactures (Bruxzir (Glidewell Laboratories), Katana (Kuraray Noritake Dental Inc), Zirlux (Henry Schein), and Zenostar (Ivoclar Vivadent Inc)) revealed greater fracture rate in the anterior compared with the posterior region and also higher fracture rate of multiunit restorations compared with single unit.[64] As discussed previously, increasing cubic phase to enhance translucency has adverse effect on material strength. Therefore, 5Y-TZP is not recommended for more than 3 units in posterior restorations.[53] Ultratranslucent zirconia offers the advantage of having the minimum thickness of 0.1 to 0.3 mm for veneers which is more conservative than the glass ceramic restorations.[65] In a recent systematic review, it has been concluded that while possessing the best mechanical feature, tetragonal zirconia polycrystalline and partially stabilized zirconia may enhance the LTD phenomenon which reduces the material strength. Fully cubic stabilized zirconia offers less mechanical advantages due to the absence of transformation toughening and is recommended in less stress-bearing situations.[66] Table 1 summarizes the results of available articles on translucent zirconia strength.

BIOLOGICAL CONSIDERATIONS

Studies have showed that monolithic zirconia accumulates microbial biofilm similar to veneered materials, and there is little concern over biologically-related complications.[70] However, there is a paucity of studies evaluating the biological behavior of translucent zirconia with different compositions.

COLOR, TRANSLUCENCY AND ESTHETICS

The most significant disadvantage of zirconia crowns is the relatively opaque appearance.[37,71] The least translucent zirconia has 42.1% translucency of a typical glass ceramic.[33,72] Two factors determine the appearance of a restoration: first the intrinsic character, which correlates with the material structure and the second is extrinsic parameters like cement layer, restoration thickness and LTD phenomenon.[73] Gloss and translucency of zirconia is brand dependent[74] and is greatly

Table 1. Demonstration of the results of available articles on translucent zirconia strength

Author	Measurement method	Material	Conclusion
Johnsson C. *et al.* 2014[22]	Loading to fracture in a wet environment using a universal testing machine	High translucent Y-TZP (Metoxit AG), High translucent Y-TZP crowns (Sagemax_ Bioceramics) Veneered high translucent Y-TZP crown core (Metoxit AG) Veneered high translucent Y-TZP crown core. (Sagemax_ Bioceramics)	The fracture strength of monolithic high translucent Y-TZP crowns is considerably higher than porcelain-veneered Y-TZP crown cores and monolithic lithium disilicate crowns
Nakamura K. *et al.* 2015[67]	Compressive loading at a crosshead-speed of 0.5 mm/ min until fracture	Monolithic translucent zirconia crowns (Lava Plus) Lithium disilicate crowns (IPS e. max press, Ivoclar/Vivadent)	Monolithic translucent zirconia crown with chamfer width minimum thickness (0.5) can be used in the molar region in terms of fracture resistance.
Zhang Y. *et al.* 2013[63]	Evaluation of toughness (by sharp indenter), and flexural strength (by universal testing machine)	Zirconia (3 mol% Y-TZP) In-house GZG (graded glass/zirconia/glass) In-house Lithium disilicate (Press- Ivoclar-Vivadent) Lithium disilicate (CAD-Ivoclar-Vivadent) Feldspathic porcelain (Vita VM9-Vita Zahnfabrik)	Monolithic ceramic restorations have superior fracture resistance against chipping and radial cracking in comparison to their porcelain-veneered restoration
Zhang Y. *et al.* 2016[69]	Crown samples subjected to failure testing by axial loading with a tungsten carbide sphere and Extended finite element modeling (XFEM)	High translucency zirconia (LAVA Plus, 3M ESPE, StPaul, MN); Lithium disilicate (IPSe.max CAD, Ivoclar-Vivadent, Amherst, NY); Resin-based composite with nanoparticle ceramic filler (LAVA UltimateRestorative, 3M ESPE, St Paul, MN)	Translucent zirconia crowns showed the highest fracture loads, lithium disilicate intermediate, and dental nanocomposite lowest.
Matsuzaki F *et al.* 2015[68]	Flexural strength evaluated by biaxial bending test	Zpex and Zpex-Yellow (Tosoh, Tokyo, Japan) Conventional opaque TZP (Tosoh, Tokyo, Japan), Veneering porcelain (CERABIEN ZR, Noritake, Tokyo, Japan)	The flexural strength of all the monolithic TZP showed approximately 1,000 MPa Colored translucent TZP is clinically useful.
Kwon S *et al.* 2017[53]	3-point bend flexural strength	Katana UTML shade A1 (Kuraray Noritake Dental) (5Y-TZP) Katana HT shade HT10 (3Y-TZP) E.max CAD LT shade A1 (Ivoclar Vivadent AG)	The flexural strength of Katana HT was significantly greater than that of Katana UTML which was significantly greater than that of e.max.

affected by grain size and content, yttria content, and amount of impurities.[37] Light scattering[73] and thickness[36,75,76] are two important factors determining the translucency of ceramic. A study showed a linear correlation between translucency and thickness of ceramic material.[77] However, other studies demonstrated an exponential relation between the translucency and thickness regardless of material shade.[78, 79] Based on an *in vitro* study, the translucency is not much affected by the thickness in zirconia, in contrast to high translucent glass ceramic in which thickness plays an essential role in determining light transmission thorough the restoration.[80,81] This fact makes the high-translucent zirconia an optimal choice in conservative anterior restoration, for example, closure of a diastema. The formation of monoclinic phase as the consequence of crack propagation and aging process may decrease zirconia translucency.[82-84] In an *in vitro* study an inverse correlation was found between zirconia translucency and strength.[85]

Translucency parameter (TP) values of 1 mm thickness human dentin and enamel have been reported as 16.4 and 18.7 respectively.[86] For translucent zirconia of different type, TP is approximately 11.2 to 15.3[3] which is less than the measured parameter for lithium disilicate (16.89).[53] With all efforts to improve the translucency of dental zirconia over the last decade, it has been generally accepted that over 0.5 mm of thickness, the translucent zirconia remains predominantly opaque[45] and is still less translucent than conventional lithium disilicate.[34] Table 2 demonstrate the summary of the articles which evaluate the optical properties of translucent zirconia.

Table 2. Demonstration of the results of available articles on translucent zirconia translucency

Author	Measurement method	Material	Conclusion
Sulaiman *et al.* 2015[87]	Reflection spectrophotometer and MARC®Resin Calibrator	Prettau® (PRT, Zirkonzahn) Bruxzir® (BRX, Glidewell) Zenostar® (ZEN, Wieland) Katana® (KAT, Noritake) Prettau Anterior® (PRTA, Zirkonzahn)	Translucency is brand and thickness dependent. Fully stabilized zirconia is relatively more translucent than partially stabilized zirconia.
Matsuzaki F *et al.* 2015[68]	Measuring translucency parameter by colorimeter	Zpex and Zpex-Yellow TZP (Tosoh, Tokyo, Japan) Conventional opaque TZP (Tosoh, Tokyo, Japan) Veneering porcelain (CERABIEN ZR, Noritake, Tokyo, Japan)	Translucent zirconia improves translucency and reach the color of porcelain without layering
Wang F *et al.* 2013[79]	Spectrocolorimeter	Lava™ Plus high translucency (3M ESPE) InCoris TZI (Sirona) Cercon R _ Base (DentsplyCeramco) Zeno R _ Zr (Wieland), Lava™ frame (3M ESPE) ZENO _Zr Translucent (Wieland)	Thickness and brand of zirconia significantly affect the translucency
Harianawala H.H *et al.* 2014[34]	Transmittance values measuring by dual beam UV Spectrophotometer	Conventional lithium disilicate (IPS e.max LT, Ivoclar Vivadent) High translucency lithium disilicate (IPS e.max HT, Ivoclar Vivad ent) Conventional zirconia (Metoxit-Pre-Sintered) High translucency zirconia (Metoxit- Pre-Sintered)	High translucent zirconia is significantly more translucent than conventional zirconia. High translucent Zirconia is significantly less translucent compared to even conventional lithium disilicate
Harada K. *et al*, 2016[74]	Spectrophotometer with an integrating sphere	Prettau Anterior (Zirkonzahn), BruxZir (Glidewell Laboratories), Katana HT (Kurary Noritake Dental Inc) Katana ST (Kurary Noritake Dental Inc) Katana UT (Kurary Noritake Dental Inc) Lithium disilicate, e.max CAD LT (Ivoclar Vivadent)	Katana UT is significantly more translucent than all other zirconia samples in 0.5mm thickness. E-max CAD LT was significantly more translucent than all zirconia samples.
Kwon S *et al.* 2017[53]	Spectrophotometer	Katana UTML shade A1 (Kuraray Noritake Dental) (5Y-TZP) Katana HT shade HT10 (3Y-TZP) E.max CAD LT shade A1 (Ivoclar Vivadent AG)	The translucency parameter of Katana HT was significantly lower than that of Katana UTML, which was significantly lower than that of e.max CAD LT

ABRASION AND WEAR PROPERTIES

The surface hardness and elastic modulus of zirconia are approximately twice[88] and three times[24] greater than that of feldspathic porcelain, respectively.[85] However, there is no correlation between the hardness of a material and abrasion of antagonist dentition.[89] It has been shown that polished monolithic translucent zirconia has the least abrasiveness, while sandblasted and subsequently glazed zirconia causes the highest abrasion of antagonist enamel.[24] Therefore, comparing antagonist wear properties, it seems polished monolithic zirconia are less abrasive compared to classic veneering ceramic [90,91] or lithium disilicate. [28,92] This property has been related to the material strength. It other word, less strength of glazing material or monolithic lithium disilicate causes the increase in surface chipping. Wear of a glassy matrix and exposure of the crystalline phase, increases the surface roughness, and abrasion of the antagonist natural dentition.[93] In other words, homogenous distribution of crystal size and orientation in monolithic translucent zirconia results in smooth surface after polishing and less abrasive behavior.[94] It has been shown that in contrast to feldspathic veneering porcelain, surface treatment of translucent zirconia has a significant effect on enamel antagonist wear.[95]

Normal enamel wear has been reported to be about 29-38 µm in natural molars and 15-18 µm in natural premolars.[96] In a clinical trial mean occlusal wear that was created by monolithic translucent zirconia (Zenostar Zr Translucent) crown was greater than that observed in natural enamel but caused less wear in enamel than other ceramic restorative materials.[15] Considering the fact that aging of materials may affect their physical property, like hardness and modulus of elasticity,[7] further investigations are needed to evaluate the effect of aging on the wearing behavior of translucent zirconia material. Table 3 summarizes some studies that evaluated the abrasive nature of translucent zirconia.

LOW TEMPERATURE DEGRADATION (LTD)

Above 1170°C, pure zirconia without stabilizer exists in a tetragonal crystalline form. Transformation from tetragonal phase to monoclinic will happen after sintering, while the temperature of the material decreases. This process will result in 4% increase in volume and a reduction in fracture resistance.[97] Dental zirconia is stabilized with 3 mol% yttria (3Y-TZP) to reduce this event.[58] With the stabilizer, under mechanical stress, tetragonal phase transforms to monoclinic in a phenomenon called transformation toughening. This phenomenon increases the zirconia resistant to micro-crack propagation.[98] The drawback of this 3 mol% yittria content is the opaque appearance of the restoration.[53]

Another transformation from metastable tetragonal phase to the monoclinic state happens in warm environment (<500°C) or humid temperature (in the absence of local stress produced at the tip of advancing crack).[99,100] This phenomenon, which is called LTD or aging of stabilized zirconia, starts in the surface of the material, gradually increasing in depth, and finally altering the bulk properties of the material.[101,102] Irrespective to the type of surface treatment, LTD will lead to roughening of the surface area,[103] development of micro-cracks, [104] and reduction in overall mechanical properties of the material (20–40% reduction in fracture load).[105]

Factors such as yttria content,[106] grain size,[107] cubic phase content,[108] Al_2O_3 and SiO_3 content,[109] and residual stress[110] determine the resistance of zirconia against LTD.[7] It has been shown that the amount of Al_2O_3 should be greater than 0.15 wt% (in a range between 0.15-0.25 wt%) to withstand aging.[111] Reduction in alumina content to 0.14 wt% to aid increased translucency in Lava Plus (Lava Plus, 3M/ESPES St. Paul, MN, USA) may lead to increase susceptibility to LTD.[46]

Even though LTD occurs mostly between 200-400°C, long exposure of the material to moist and heat in oral cavity may also result in LTD. The main causative factor of aging is still unknown, OH-group may be responsible in breaking atomic bond and produce residual stress and generate transformation phase.[49] In veneered zirconia restorations, the ceramic veneer protects the strong core from direct exposure to the oral environment. However, monolithic translucent zirconia does not have such a barrier and is more susceptible to LTD.[112] One study showed that translucent Y-TZP are even more susceptible to LTD in comparison with traditional zirconia.[82] Another study which assesses flexural strength of different brands of translucent zirconia after accelerated aging revealed that the reduction in material strength was brand dependent and correlated with the depth of LTD.[113]

It has been shown that even though the increased monoclinic phase after aging phase results in low fracture resistance of translucent zirconia (Lava Plus, 3M/ESPES St. Paul, MN, USA) crown, the restorations still maintained strength.[102]

ABUTMENT PREPARATION REQUIREMENTS

In conventional ceramic crowns, axial clearance should be 1.5 mm and occlusal clearance approximately 2 mm.[114] The recommended thickness for translucent zirconia based on *in vitro* studies is 0.5 mm for occlusal and axial surfaces. It has been shown that translucent zirconia (Lava Plus, 3M/ESPES St. Paul, MN, USA) in 0.5 mm thickness has higher fracture strength than lithium disilicate with 1.5 mm occlusal thickness.[67] In implant supported restorations, 0.5 mm thickness for occlusal surface has a high risk of fracture. When the antagonist arch consists of natural dentition, with a buffering effect of the periodontal ligament, 0.7 mm thickness is recommended. When the antagonist dentition is a fixed implant supported restoration, more thickness (about 0.8mm) is recommended.[57] It has been proven that the strength of a zirconia restoration depends on the occlusal thickness.[115, 116]

A connector size of 9 mm^2 has been recommended for restorations made of translucent zirconia; for comparison, lithium-disilicate restorations require a 16 mm^2 connector area for the same strength.[16]

A light chamfer[67] or round shoulder finish line is recommended with 0.5 mm thickness. The preparation recommendations follow the traditional zirconia restoration guidelines[16]. The marginal gap for a CAD/CAM restorations should be between 17 to 118 µm for clinical acceptance.[117] Marginal discrepancy for a full anatomic zirconia restoration has been reported between 100-120 µm,[118] which is more than the mean marginal gap of IPS e.max®press[1] but without an acceptable clinical range and comparable with veneered zirconia and metal-ceramic crowns.[119] Comparing the marginal discrepancy of a single and 14-unit framework made of translucent zirconia (Ice Zirkon Translucent 95H18, Zirkonzahn S.r.l.), it was revealed that single unit frameworks showed significantly less marginal gap and less time was needed to adjust the framework than 14-unit frameworks (90 µm cement-gap in single unit compared to 124 µm cement-gap in 14-unit frameworks).[120] Table 4 summarizes the available articles concerning the fitness of translucent zirconia.

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Table 3. Demonstration of the results of available articles on translucent zirconia wear behavior

Author	Measurement method	Material	Conclusion
Park J.H *et al* 2014[91]	Surface tooth wear with a field emission scanning electron microscope (FE-SEM)	Prettau Zirkonzahn (polished) (PRT, Zirkonzahn) Prettau Zirkonzahn (with staining) (PRT, Zirkonzahn) Prettau Zirkonzahn (with staining and glazing) (PRT, Zirkonzahn) ZirBlank (Acu cera Inc) ZenoZr (WielandDental) Cerabien ZR (Noritake) (feldspathic veneering)	All zirconia groups showed significantly lower enamel wear than the Feldspathic ceramic group. Staining and glazing the zirconia substructure caused more antagonistic tooth wear in comparison with polished surface
Stober T. *et al.* 2014[15]	Enamel wear evaluation by plaster replicas and 3D laser scanning methods	Pre-shaded, yttrium-stabilised zirconia (Zenostar Zr Translucent)	Amount of antagonistic enamel wear after 6 months is comparable or lower than, that caused by other ceramic materials.
Stawarczyk B. *et al.* 2013[24]	Two-body wear characteristics of zirconia and enamel antagonists with a 3D profilometer and under scanning electron Microscopy	Veneered zirconia Glazed zirconia using a glaze ceramic Glazed zirconia using a glaze spray Manually polished monolithic zirconia Mechanically polished monolithic zirconia Monolithic base alloy All were (DentaNEM, WielandDental, Technik, Pforzheim, Germany)	Polished monolithic translucent zirconia showed lower wear rate on enamel antagonists as well as within the material itself. Polished monolithic translucent zirconia developed higher rates of enamel cracks.
Hara M. *et al.* 2014[88]	Wear performances of bovine tooth enamel using an experimental wear simulator, SEM and electron probe microanalyzer	Translucent TZP (Zpex100, Tosoh) Feldspar porcelain (VITA VMK Master Translucent, VITA Zahnfabrik)	Wear of the bovine tooth enamel substrates against the translucent zirconia abraders was less than feldspar porcelain abrader
Kwon S *et al.* 2017[53]	Wear-testing device. The volumetric measured using a noncontact profilometer	Katana UTML shade A1 (Kuraray Noritake Dental) (5Y-TZP) Katana HT shade HT10 (3Y-TZP) E.max CAD LT shade A1 (Ivoclar Vivadent AG)	No detectable material or opposing enamel wear was recorded

Table 4. Demonstration of the results of available articles on translucent zirconia restoration fitness

Author	Measurement method	Material	Conclusion
Sach s C. *et al.* 2014[120]	Comparing the marginal fit of single crowns with 14-unit frameworks by binocular microscope	Pre-sintered zirconia blanks (Ice Zirkon Translucent 95H18, Zirkonzahn S.r.l.)	Single crowns showed significantly better accuracy of fit. Both restorations showed clinically acceptable marginal fit.
Ji M.K. *et al.* 2015[1]	Comparing the marginal fit of crowns by light microscope equipped with a digital camera	Prettau® (PRTA, Zirkonzahn) Zenostar® (ZEN, Wieland), IPS e.max®press (IvoclarVivadent AG, Schaan, Liechtenstein)	IPS e.max®press had significantly smaller marginal gap. The measured marginal gaps all ceramic crown were clinically acceptable.

GLAZE AND ADJUSTMENT

If occlusal adjustment is needed after delivery, the restoration could be polished using diamond impregnated silicone instrument[121] and polishing paste which contain up to 20% diamond particles with a grain size of 2 to 4 µm and a maximum rotational speed of 15,000 rpm.[122] This process will maximize the brightness of final restoration.[37] However, it is highly recommended to carry out surface form adjustments before sintering in order to achieve a more natural looking contour and to avoid microroughness.[123] For occlusal adjustment, the use of a special diamond instrument with diamond grit (eg, ZR grinder, Komet, Gebr. Brasseler; or K-Diamonds, Edenta) under water cooling has been recommended. The greater performance and durability have been achieved with this instrument compared with conventional instruments.[16] Due to minimum thickness and inherent brittleness of zirconia, during laboratory finishing and clinical adjustment, careful attention should be given to the marginal area to avoid chipping.[123]

Monolithic translucent zirconia can also be adjusted using surface staining or a glaze spray. More esthetic results might be achieved by coloring presintered zirconia with an infiltration technique.[16] Here, non-colored pre-sintered zirconia is immersed in a colored liquid or the color is applied on the material using a brush.[124-126] Fischer *et al.* introduced a multi-color concept for translucent zirconia. This method is especially useful when occlusal adjustment is anticipated and translucency of the monolithic material compromises the esthetic results.[16] It should also be considered that any coloring process may affect the physical and visual aspect of dental zirconia. It has been shown that coloring liquid had no effect on translucency of partially stabilized translucent zirconia, while it decreased the translucency of fully stabilized translucent zirconia types. Another outcome of this study was that coloring decreased the flexural strength of partially stabilized translucent zirconia. However, it enhances the flexural strength of fully stabilized translucent zirconia.[113]

It has also been suggested that a finishing and polishing process, rather than glazing provides a more natural texture.[123] As the glaze layer will typically be worn away after 6 months, [7,127] and the zirconia is exposed to the oral environment, aging will be accelerated. Further investigations should be performed to evaluate the consequence of low temperature degradation in this situation.[105]

SURFACE TREATMENT AND CEMENTATION

A main concern for the use of translucent zirconia when used to fabricate a conservative restoration is reduced surface area available for bonding to the abutment structure. Some recommendation to improve bond strength include: air-abrasion with aluminum oxide particles,[128] tribochemical silica coating and subsequent use of a silane agent,[129] application of resin cement which contain MDP monomer,[130,131] plasma processing, silica infiltration by the sol-gel technique,[132] infiltration of feldespatic glass ceramic,[133] selective infiltration-etching method,[134] glaze-on technique[135] and heated silane.[136] Dual cure materials are a popular choice for cementation of ceramic restorations.[137] In an *in vitro* study conducted to compare the bond strength of 3Y-TZP (Katana HT), 5Y-TZP (Katana UTML) and lithium disilicate (E.max CAD LT shade A1 (Ivoclar Vivadent AG)), no significant difference was found between the result of shear bond strength of the different samples cemented with resin cement.[53]

The use of light cure materials for cementing the ceramic restorations are affected by light attenuation and subsequent curing procedure of the cement. Therefore, ceramic composition, shade, thickness, translucency, size and distribution of defects, and porosity influence light transmission thorough the restoration.[138-140] Other factors that affect light polymerization are composition of resin cement, power of curing light, curing duration, and the distance between the light cure tip and restoration.[141] Although some light attenuation is inevitable due to the opaque nature of zirconia, a previous study has reported, acceptable polymerization (more than 50%) using a dual polymerization cement.[87] A further issue is that the final appearance of the more translucent restoration is affected by cement color and translucency.[142] Therefore, considering esthetic demands, using a try-in paste cement could be advantageous.

Resin cement material, should have acidic group (phosphate or carboxylate) for chemically bonding to zirconia.[143,144] Grit-blasting with alumina particles is recommended for an improved bond strength[53]. However, as the transformation toughening is reduced by increasing the yittria content, in the absence of transformation toughening, treating the surface with air abrasion may lead to a decrease in strength characteristics.[74] In addition, it has been shown that sandblasting with Al_2O_3 did not result in an increased surface roughness of translucent zirconia. Residual stress and crystalline phase content in samples were influenced by sandblasting.[145] It seems that type of cement does not significantly affect the stress distribution of single monolithic translucent zirconia.[146] In darker shade zirconia ceramics (A3/A3.5/A4/B3/B4/C3/C4/D3), application of dual-cured cement with less sensitivity to light attenuation are beneficial.[80]

Chan and Boyer found that for a thin ceramic (0.5mm) the curing time must be increased for approximately 40% of the exposure required for curing the resin composite without ceramic (not a cement material). When the thickness increased to 1 mm, the curing time must be doubled. Based on the Beer–Lambert law in all materials as the thickness increase, the translucency will decrease. For a specific type of ceramic, no difference was reported in light transmission until the distance between the tip of curing appliance and the target reached 3 mm. It has been shown that in translucent materials (e.g. glass ceramic) the effect of thickness on light transmission is significant. As the translucency decrease (e.g. zirconia), light transmission would not be affected dramatically by thickness.[38] Further investigation in this field is required to clarify the complications.

CONCLUSIONS

Reviewing the available articles on monolithic translucent zirconia, the following conclusions can be made:

1. Different methods have been introduced to make zirconia translucent.
2. The strength of translucent zirconia restoration is less than traditional zirconia base restorations.
3. Translucent zirconia abrades the antagonist dentition less than other esthetic ceramics.
4. More information about the effect of LTD on different aspect of translucent zirconia is needed.
5. In restoring natural dentition and for root-form implants, a minimum recommended thickness is 0.5mm and 0.8mm, respectively.
6. With all benefits of translucent zirconia, sufficient translucency for optimal aesthetic effects in anterior restorations has yet to be fully realized.

CONFLICT OF INTERESTS

The authors deny any conflict of interests.

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