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Effect of zirconia thickness of fixed partial prostheses on the light-curing irradiation of the resin cement: an integrative review.

Rafael de la Bella Garzón

Dissertação conducente ao Grau de Mestre
em Medicina Dentária (Ciclo Integrado)

Gandra, 25 de Julho de 2020

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Trabalho realizado sob a orientação do Professor Doutor Júlio C. M. Souza

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O Orientador

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IV

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A mi familia. Gracias por apoyarme, soportarme, por no dejarme caer, estar ahí siempre en esta larga etapa y durante toda mi vida. Esto es vuestro.

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Gracias al Laboratorio Dental García Latorre, por dejarme entrar en vuestra casa y compartir conmigo toda vuestra larga experiencia. De nuevo, gracias Isaías y Elvira.

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RESUMO

O principal objectivo deste trabalho foi realizar uma revisão sistemática integrativa a respeito do efeito da espessura da zircónia sobre a irradiação de luz visível necessária para a polimerização dos cimentos resinosos.. Uma pesquisa eletrônica foi realizada na base de dados de publicações científicas PUBMED usando a combinação dos seguintes termos científicos: zirconia, translucence, light curing, thickness, light irradiation, glass ceramic, polymerization, resin cement, Y-TZP and microstructure. A pesquisa identificou 117 artigos, dos quais 22 foram considerados relevantes para este estudo. Esses estudos forneceram dados importantes levando em consideração a espessura da zirconia, microestrutura do material e tipo de material, tipo de cemento resinoso a utilizar, resistência de acordo com a espessura, transmitância da luz, intensidade da luz. Os estudos indicaram que aumento da espessura da estrutura da zircónia de 0,5 para 2 mm resulta numa diminuição significativa da transmissão da luz através do material e afecta negativamente à polimerização do cimento resinoso. A transmissão de luz e polimerização do material resinoso é também afectada pela tonalidade, quer seja opaco, translúcido ou muito translúcido e pela composição química dos materiais. A partir da seleção de materiais mais translúcido sem afetar o desempenho mecânico, é possível garantir a passagem de luz através do material e consequente grau de conversão e propriedades do cimento resinoso. De fato, a microestrutura, a espessura e a translucidez são fatores-chave para promover a passagem de luz visível e energia necessária para a polimerização do cimento resinoso durante a cimentação de próteses de zircónia.

PALAVRAS-CHAVE

Zirconia, light curing, thickness, light irradiation, resin cement.

ABSTRACT

The main objective of this work was to perform an integrative review on the light irradiation through zirconium-based fixed prosthetic structures, taking into account the thickness and microstructure of the zirconia. An electronic search was carried out on PUBMED database using the combination of the following scientific terms: zirconia, translucence, light curing, thickness, light irradiation, glass ceramic, polymerization, resin cement, Y-TZP and microstructure.

The research identified 117 articles, of which 22 were considered relevant for this study. These studies provided important data taking into consideration zirconia thickness, microstructure, shading, light transmittance, light-curing parameters, type of zirconia and resin cement. The increase in the zirconia thickness from 0.5 to 2 mm results in a significant decrease of light transmission through the material. That and negatively affects the degree of conversion and properties of the resin-matrix cement. The light-curing process of resin cement is also affected by the shade, chemical composition, and microstructure of zirconia and resin cement. Optimum conditions of light-curing are required to reach the threshold intensity of light and energy for polymerization of resin-matrix cements. Thus, thickness, microstructure, shade of zirconia prosthetic structures are key factors to promote a proper polymerization of resin-matrix cements during the cementation procedure.

KEYWORDS

Zirconia, translucence, light curing, thickness, light irradiation, resin cement.

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1. INTRODUCTION

Yttria-stabilized tetragonal zirconia polycrystalline (Y-TZP) is a high-strength polycrystalline zirconia developed for different industrial applications including biomedical materials such as prosthetics and implants. YTZP become one of the most versatile polycrystalline ceramics. On such type of zirconia, the amount of yttrium oxide (yttria) consists of around 3 mol% (3Y-TZP) leading to a content of tetragonal phase of approximately 50%[(1–4)] .Due to its higher opacity, 3Y-TZP has been used as a prosthetic framework material in which a veneer glass-ceramics can be applied for aesthetic improvements. The thickness of the material determines the strength (flexural strength up to 1200 MPa and fracture toughness of around 8 MPa.m1/2) and the optical characteristics of the overall structure [(1,5,6)] .3Y-TZP frameworks have the convenient opacity to mask all shades of discolored background which involve also metallic abutments[(1,4)]. Nevertheless, light transmission is reduced because the opaque tetragonal phase[(3,4)]. Lower light scattering and more uniform light emission are dependent on the zirconia translucency in zirconia prosthetics[(4,7)] .

As a consequence for adhesion of the zirconia prosthetics, the light-curing of resin-matrix cements can be interfered due to the low translucency of the ceramic materials. Therefore, light transmission is limited by the thickness or opacity of the zirconia prosthetics. Indeed, low transmittance is expected through thick layers of YTZP, which explains the relatively light irradiation procedures used when cementing light-activated resin-matrix compounds. Optimal light-curing is possible through ceramic materials with thickness below ≤4 mm which is associated with both clinical advantages and fundamental improvements in material properties.[(8,9)]

Current changes in the formulation of zirconia resulted in a recent class of monolithic highly translucent zirconia with a different molecular structure and physical properties and a more attractive aesthetic appearance[(2,3)]. However, monolithic YTZP has recently gathered attention for manufacturing crowns, veneers, on-lay, or in-lay[(5,10)]. KATANA Zirconia Super

Translucent Multi-Layered Disk (STML) is a fully stabilized zirconia and is different from the rest due to the higher yttrium oxide content, which makes it more translucent. Named "fully stabilized zirconia" with a mixture of cubic and tetragonal and a cubic content of more than 50% up to 53%[(4)]. Prettau Anterior, Zirkonzahn, Gais, Switzerland, ultratranslucent zirconia (500 to 800 MPa), has 0.11% to 0.26% alumina and a yttria concentration close to 12%.[(5)]

The cubic content was increased by adding a larger amount of yttrium oxide (approximately 5-8 mol%)[(1,11)]. Monolithic translucent zirconia ceramics contain above 50% of cubic crystals, which increase translucency but are detrimental to the mechanical properties.[(1,4)] The microstructure and thickness of zirconia and the light-curing mode (plasma, high, and standard power mode) influence the light transmitted irradiance. Optimal light-curing is possible through ceramic materials with thickness below ≤4 mm although at high translucence conditions[(8,9)] . The increased thickness ranging between 2 and 4 mm negatively affects the light transmission to the underlying resin cements and results in a significant decrease in mechanical properties of the cementation layer[(8,12,13)].

Dual-curing luting resins combine the desirable properties of chemical and light-curing materials to guarantee the degree of conversion of monomers in the case of insufficient light transmission[(6,14)]. Nevertheless, the degree of conversion of the organic matrix of resin cements must be enhanced that corresponds to an efficient polymerization of resin-matrix materials. As a result, the strength of the adhesive interface is increased leading to a long term performance of the zirconia-based prosthetics. In the dental clinics, the irradiance (wavelength range 360 to 540 nm) and energy should periodically be measured by spectrometers to avoid failures within the light-curing procedure[(9,15)].

The main aim of this work was to perform an integrative review on the light irradiation through zirconia-based fixed prosthetic structures considering zirconia thickness and microstructure. It was hypothesized that thick zirconia-based restorations attenuate the light irradiation towards to the resin cements during the light-curing procedure. Also, the type of veneering glass-ceramics can affect the light irradiation and therefore the light-curing procedure could be adjusted for different zirconia restorations.

2. METHODS

A literature search was performed on PUBMED (via National Library of Medicine) using the following combination of search terms: "zirconia" OR "YTZP" AND "translucency" OR "thickness" AND "microstructure" OR ¨light irradiation¨ OR "LED" OR "polymerization" OR "light-curing". The inclusion criteria involved articles published in the English language, reporting the influence of zirconia thickness on the light-curing irradiation for cementation. The eligibility inclusion criteria used for article searches also involved: articles written in English; meta-analyses; randomized controlled trials; and prospective cohort studies. The total of articles was compiled for each combination of key terms and therefore the duplicates were removed using Mendeley citation manager.

Two of the authors (JCMS, RG) independently analyzed the titles and abstracts of potentially relevant articles. A preliminary evaluation of the abstracts was carried out to establish whether the articles met the purpose of the study. Selected articles were individually read and evaluated concerning the purpose of this study. The following factors were retrieved for this review: author's names, journal, publication year, purpose, type of zirconia, thickness, light curing and main outcomes.

3. RESULTS

The literature search on PUBMED identified a total of 117 articles, as shown in Fig. 1. A total of 92 duplicates were removed. After reading the titles and abstracts of the articles, 3 articles were excluded because they did not meet the inclusion criteria. The remaining 22 potentially relevant studies were then evaluated (Fig. 1). Of those studies, 4 were excluded because they did not provide comprehensive data considering the purpose of the present study. Thus 18 studies were included in this review.

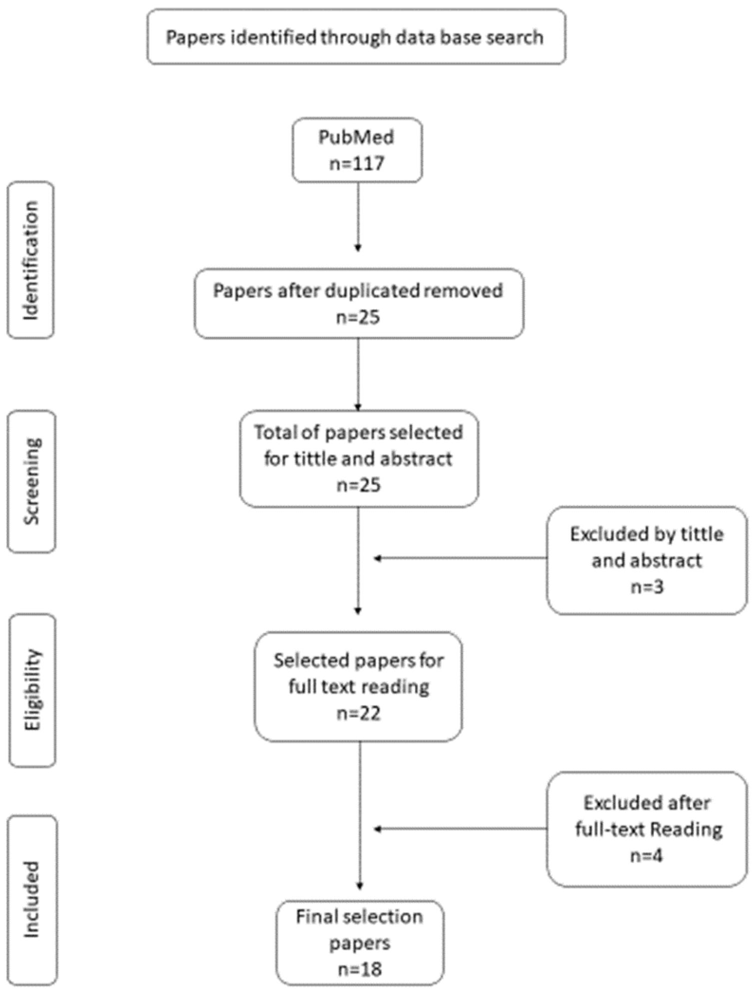

Figure 1. Flow diagram of the selection of articles.

Of the 18 studies selected, 12 (60 %) evaluated the effect of zirconia translucency, surface polishing, thickness, color on different types of zirconia, 3 (20%) articles evaluated the degree of conversion and the limitations of the light-curing procedure. Three (20%) articles evaluated the effect of the bond strength of zirconia to the resin-matrix cement. The retrieved data from the selected studies are given in Table 1.

Table 1. Relevant data gathered from the retrieved studies.

AUTHOR (YEAR)	PURPOSE	ZIRCONIA TYPE	THICKNESS	LIGHT CURING IRRADIATION	LIGHT-CURING IRRADIATION THROUGH THE ZIRCONIA	DEGREE OF CONVERSION (%) OR MICRO-HARDNESS (HV OR HK)
Inokoshi et al. (2016)	Evaluation of the light-curing irradiation on the degree of conversion of three composite cements	Two ytria stabilized zirconia (YSZ), Aadva (GC; Tokyo, Japan) and KATANA (Kuraray Noritake; Tokyo, Japan), and one ceria-stabilized tetragonal zirconia polycrystal/alumina (Ce-TZP/Al2O3): NANOZR (Panasonic; Osaka, Japan).	0.5- and 1.5-mm-thick zirconia, and 0.5-mm-thick zirconia veneered with a 1.0-mm-thick veneering ceramic	Used a modified light spectrometer disassembled from a MARC patient simulator (Blue Lights Analytics; Halifax, Nova Scotia, Canada). Light cured for 40 seg using either G-Light Prima or SmartLite FOCUS. 10mW/cm^2, corresponds to 0.4J/cm^2	Through the NANOCR zirconia was quite low (<0,4 J/cm^2). Through YSZ zirconia (Adava and KATANA) not different from that of specimens that were cured with-out interposition of zirconia.	Each specimen was collected at 5 and 10 min, 1 and 24 h, and at 1 week after light curing. Clearfil Esthetic Cement and Gaenial Universal Flo reached over 80%. G-CEM LinkAce and Panavia F2.0 (range: 70% to 80%). interposition of Ce-TZP/Al2O3 zirconia result in significantly lower DC (range: 15% to 60%). 5 min after ranged (40% to 50%) to (70% to 80%) one week after. Clearfil Esthetic Cement after 5min around 60% and one week after 75% to 80%. Through the opaque Ce-TZP/Al2O3 (NANOZR) zirconia: Panavia F2.0 (20% to 30%) to (70% to 75%)
Menezes de Mendoza et al. (2019)	Evaluate the effect of the transmittance of different composition	Ivoclar Vivadent AG; Schaan, Liechtenstein) with low translucency (LT) and medium opacity (MO), and zirconia ceramic (Z) (IPS e.max® ZirCAD, Ivoclar Vivadent AG; Schaan, Liechtenstein)	Thicknesses 1mm for Z ceramics had been achieved (2.5 mm high and 10.0 mm diameter) and the remaining space (2.0 mm thick) was covered with veneering ceramic (IPS e.max® Ceram, Ivoclar Vivadent AG; Schaan, Liechtenstein	The transmittance was measured by direct transmission method using a spectrophotometer (UV 1800 spectrophotometer, Shimadzu; Kyoto, Kyoto, Japan). The intensity of light transmitted through the specimen was measured continuously at 1 nm intervals, at visible light wavelengths (λ), from 400 to 700 nm	Z (0.078%) ceramics.	VariolinkII: Z: B2-59,78% C2-59.25% A2-58,98% A3,5-58,5% D3-57,65% Rely X U 200: Z: C2-55,83% D3-54,83% B2-53,63% A2-53,40% A3,5-50,83%

AUTHOR (YEAR)	PURPOSE	ZIRCONIA TYPE	THICKNESS	LIGHT CURING IRRADIATION	LIGHT-CURING IRRADIATION THROUGH THE ZIRCONIA	DEGREE OF CONVERSION (%) OR MICRO-HARDNESS (HV OR HK)
Alovisi et al. (2017-2018)	Assessment of (DC), (MH) and bond strength of two dual-curing resin cements under translucent monolithic zirconia irradiated with different protocols	Katana UTML, Ultra Translucent Multi Layered, Standard Shade A1-D4, Kuraray Noritake Dental Inc., Tokyo, Japan	1mm	Power multi-LED lamp AT 1400mW/cm². no irradiation (Subgroup A); 20 s of irradiation (Subgroup B). 120 s of irradiation (Subgroup C).		Rely-X Ultimate No light:29.7A +/-4.8 20s: 63.3B+/-2.9 120s: 62.9B+/-1.9 Panavia SA No light: 29.3A+/-10.2 20s: 52.8B+/-5.7 120s: 58.1B+/-5.2
Caprak et al. (2018)	Translucency of CAD/CAM blocks influences the polymerization	Resin nanoceramic Lava Ultimate, ceramic Vita Enamic, VITA Zahnfabrik, Zirconia-reinforced lithium silicate ceramic Vita Suprinity, VITA Zahnfabrik, Feldspathic ceramic Vitablocs Mark II, VITA Zahnfabrik, Ivoclar Vivadent AG	Diameter of 6 mm and a thickness of 2 mm were fabricated using the Cercon (DeguDent GmbH, Hanau-Wolfgang, Germany)	LED light source (HS-LED1500; Henry Schein, Ontario, Canada) a mechanism holding the tip perpendicular to and in contact with the ceramic disc was lasted for 40 seconds	VITA Easyshade Advance 4.0 spectrophotometer (VITA Zahnfabrik) with a 400 to 700 nm wavelength	Vickers hardness measurements were conducted at 100, 300, 500, and 700 μm
Hardy (2017-2018)	Limitations of using light-curable resin-based luting composites (RBLCs), light transmittance and degree of conversion (DC)	Yttria-stabilised zirconia ceramic, LAVA-Zr, LAVA Ultimate	CAD/CAM blocks 10 mm diameter disc-shaped filters of 4 different thicknesses: 0.5, 1,2 and 4 mm (±0.01 mm).	UV–vis spectrometer (USB4000, Ocean Optics, UK;(n = 3) 1 mm thick, 5 mm diameter Teflon molds, covered on each side with a polyester film, 40 s light irradiation	Calibrated around 1000 mW/cm². The irradiance values were measured with the Thorlabs Optical Power and Energy Meter PM100USB at 1020 mW/cm² for AURAviolet, 1030 mW/cm² for AURAblue and 1119 mW/cm² for the BPG2	Raman spectroscopy (DXR Raman Micro-scope, Thermo Scientific, Madison, WI USA) 2.4 and 5.0% for AURAblue, and between 0.42 and1.93 for AURAviolet. 250 and 500 mW/cm²
Ilie et al. (2015)	Evaluate the amount of light (360 to 540 nm) that passes through the zirconia with a respective material thickness	Conventional zirconia (negative control) Ceramill ZI (Amann Girrbach), Monolithic zirconia DD Bio ZM Translucent (Dental Direkt), GC ZR Disc CIP (GC Europe), ZENOStar (Wieland+Dental), Prettau (Zirkonzahn), Ceramill Zolid (Amann Girrbach), InCoris TZI (Sirona), Glass ceramic (positive control) VITA Mark II A2 (VITA Zahnfabrik)	Zirconia(12 mm wide × 12 mm long) and glass ceramic disks (10 mm wide × 10 mm long) were cut with a high performance cut-off machine (Secutom-50; Struers) in the following thicknesses: 0.5, 1, 1.5, 2, 2.5, and 3 mm	0.76 to 0 .96 (.76 for Ceramill ZI,0 .77 DD Bio ZM, 0 .79 GC ZR Disc CIP,0 .80 ZENOStar, 0.80 Prettau, 0.81 Ceramill Zolid,0 .81 InCoris TZI,0 .96 VITA Mark II)	Ranges from 122.0 mW/cm² to 536.7 mW/ cm², in order: Prettau (122.0 to 324.0 mW/ cm²), InCoris TZI (136.6 to 369.6 mW/ cm²), DD Bio ZM (153.0 to 417.2 mW/ cm²) Ceramill Zolid (156.9 to 418.4 mW/ cm²) ZENOStar (158.6 to 426.4 mW/ cm²) Ceramill ZI (167.0 to 447.0 mW/), cm²GC ZR Disc CIP (171.2 to 469.5 mW/cm²) VITA Mark II (190.3 to 536.7 mW/ cm²)	

AUTHOR (YEAR)	PURPOSE	ZIRCONIA TYPE	THICKNESS	LIGHT CURING IRRADIATION	LIGHT-CURING IRRADIATION THROUGH THE ZIRCONIA	DEGREE OF CONVERSION (%) OR MICRO-HARDNESS (HV OR HK)
Lee et al. (2016)	Evaluate how zirconia thickness affects the shear bond strength (SBS) between zirconia and dual cure resin cement	Zirconia (LAVA, 3M-ESPE, Saint Paul, MN, USA)	40 blocks of 1 mm thickness zirconia and 20 of each 1.5 and 2 mm, abrasion (Microetcher II Kit, Danville materials, San Ramon, CA, USA) with 50 µm aluminum-oxide (Al2O3) particles	Group A/ 10 blocks/ 1 mm/20s. Group B/ 10 blocks /1 mm 3 mm glass panel below/20s Group C/ 10 blocks/1.5 mm glass panel below for 20s Group D/10 blocks/ 2 mm /20s Group E/ 10 blocks /1 mm/ 40 s Group F /10 blocks/1 mm, the glass panel below/ 40 s. Group G/ 10 blocks /1.5 mm, the glass panel below/ 40 s. GroupH/10 blocks/2 mm/40 s	Light source of polymerizing unit (Dr's Light AT, Good Doctors, Incheon, Korea) was high power Light Emitting Diode (LED) with light intensity ±1.400 mW/ cm^2 (wavelength range 440 to 490 nm)	
Liebermann et al. (2018)	Evaluate the transmittance of visible light and blue light through zirconia	Bruxzir (BX) Cercon (CE) Lava Frame (LF) Lava Plus (LP) Prettau (PT) Zenostar (ZS) LS2 (EM)	Bruxzir 0.5 and 1 mm Cercon HT 0.4 and 1 mm Lava Frame 0.3 and 1 mm Lava Plus 0.3 and 1 mm; Prettau 0.5 and 1 mm Zenostar 0.4 and 1 mm	Spectrophotometer (Lamda 35 Perkin Elmer, Perkin Elmer, Waltham, MA, USA) light with a wavelength between 200 to 800 nm (1 nm intervals), opening width of 2 mm and scan speed of 460 nm/mi	E.max_HT 1 mm23.50 % ; Bruxzir 1 mm 12.00%;Lava Frame 1 mm 7.54%; Lava Plus 1 mm 8.44%; Prettau 1 mm 8.11%; Zenostar 1 mm4.80 %; Cercon_HT 1 mm 7.67%	
Rocha Pacheco et al. (2018)	Influence of the type of material in indirect restorations at different thicknesses on the transmission of different wavelengths	[RC] resin/ceramic hybrid material (Lava Ultimate, 3M ESPE, St. Paul, MN, USA); [FC] feldspathic ceramic (VitaBlocs Mark II, Vita Zahnfabrik, Bad Säckingen, Germany) and two Y-TZP zirconia ceramics: [ZK] zirconia 1 (Katana, Kuraray Noritake Dental Inc., Tokyo, Japan) and [ZL] zirconia 2 (Lava Zirconia, 3 M ESPE, St. Paul, MN, USA)	Samples (15 x15 mm): 0.5 mm, 1.0 mm, 1.5 mm, and 2.0 mm	Spectroradiometer (USB 2000, Ocean Optics, Dunedin, FL, USA). With no interposing ceramic specimen). Specific data regarding the violet (350–425 nm) and blue (425–490 nm). absorbance coefficient: 400 nm (violet), 450 nm. (blue), and 500 nm (green). 927.2 +/- 1.2	Resin-ceramic 0.5mm(57.4%)- 1.0mm(75.3%)- 1.5mm(83.5%)- 2.0mm(88.8%) Feldspathic ceramic 0.5mm (50.5%) 1.0mm (60.9%) 1.5mm (69.4%) 2.0mm (80.0%) Zirconia 1 0.5mm (66.1%) 1.0mm (78.7 %) 1.5mm (88.3%) 2.0mm (92.3%) Zirconia 2 0.5mm (67.2%) 1.0mm (74.1%) 1.5mm (77.4%) 2.0mm (82.1%)	Zirconia 1 400nm (y=0,6973x+ R= 0,9982) 450nm (Y=0,4353x+0,24) R=0,9974) 500nm (y=0,381x+0,2508 R=0,996 Zirconia 2 400nm (y=0,282x+0,4286 R=0,9907) 450nm (y=0,1766x+0,4067 R=0,9823) 500nm (y=0,1604x+0,3902 R=0,9782

AUTHOR (YEAR)	PURPOSE	ZIRCONIA TYPE	THICKNESS	LIGHT CURING IRRADIATION	LIGHT-CURING IRRADIATION THROUGH THE ZIRCONIA	DEGREE OF CONVERSION (%) OR MICRO-HARDNESS (HV OR HK)
Sulaiman et al. (2015)	Estimate the effect of polishing on the surface gloss of monolithic zirconia, measure and compare the translucency and effect of zirconia thickness on irradiance	Partial stabilized zirconia (PSZ) Prettau Zirconia, Bruxzir Zirconia, Wieland Zenostar Translucent,Katana High Translucent,Fully stabilized zirconia (FSZ) Prettau Anterior,Control (PSZ) ICE Zircon	10 mm × 10 mm, n = 5/per subgroup) were cut into different thicknesses (0.5, 0.7, 1.0,1.2, 1.5, and 2.0 mm) using (Struers Secotom-50, Copenhagen, Denmark)	LED light-curing unit (Elipar S10, 3 M ESPE, St. Paul, MN,USA) with light irradiance of 1200 mW/cm², wavelength range430−480 nm and curing time 10 s	PRT 0.5 mm 16.97% 0.7mm 14.50% 1.0mm 11.16% 1.2mm 9.82% 1.5mm 7.76% 2.0mm 5.61% PRTA 0,5mm 19.95 % 0,7mm 17.23% 1.0mm 15.03% 1,2mm 13.48% 1,5mm 11.52% 2,0mm 9.17% BRX 0,5mm 17.03% 0,7mm 14.22% 1.0mm 11.58% 1,2mm 9.66% 1,5mm 7.33% 2,0mm 5.10% ZEN 0,5mm 17.99% 0,7mm 15.27% 1.0mm 12.98% 1,2mm 10.92% 1,5mm 8.75% 2.0mm 6.83% KAT 0,5mm 17.57% 0,7mm 15.11% 1,0mm 13.42% 1,2mm 11.69% 1,5mm 9.78% 2,0mm 7.78%	

AUTHOR (YEAR)	PURPOSE	ZIRCONIA TYPE	THICKNESS	LIGHT CURING IRRADIATION	LIGHT-CURING IRRADIATION THROUGH THE ZIRCONIA	DEGREE OF CONVERSION (%) OR MICRO-HARDNESS (HV OR HK)
Turkoglu et al. (2019)	Investigate the effects of the type and thickness of the zirconia material on the microhardness of the underlying dual-cure resin cement	Prettau Zirconia Zirkonzahn GmbH Bruneck, Italy Prettau Anterior, Zirkonzahn GmbH	0.5mm 1.0mm 1.5mm 2.0mm	LEDcuring unit (Elipar S10, 3 MESPE, Seefeld,Germany) wavelength of 430-480 nm and a power density of 1200mW/cm² time of 20 s		PRZ 100μm 62.53±7.53 300 μm 56.04±6.40 500 μm 46.31±7.01 PRA 100 μm 66.46±8.45 300 μm 60.11±6.55 500 μm 52.88±6.81
Turp et al. (2015)	Effect of thickness of zirconia on curing efficiency of resin cements	Zirconia blocks (Kavo Everest BIOZS-blanks) KaVo Dental GmbH, Baden-Wurttemberg, Germany) Feldspathic (GC Initial Zr, GC Europe, Leuven, Belgium)	(G) 0.5 mm zirkonya control, (G1) 0,5 mm zirkonya ve 0,5 mm feldspatik, (G2) 1.0 mm zirkonya 0.5 mm	LED curing unit (Elipar S10, 3M, ESPE, Saint Paul, MN, USA) for 20 s, wavelength range of 430-480 nm, 1200 mW/cm²	G 7.21±0.09 7.18±0.23 0.601 G1 6.76±0.33 6.66±0.37 0.488*/ G2 6.31±0.34 4.80±0.27 0.001** G3 4.42±0.73 4.12±0.72 0.332	Wolpert Wilson Instruments, 400 Series Vickers Hardness Tester, Esslingen, Germany,50g, 100µm- 300µm and 500µm
Vidotti et al. (2017)	The bond strength of resin composite cemented to (Y-TZP	(Y-TZP) (IPS e.max ZirCAD, Ivoclar Vivadent; Schaan, Liechtenstein)	dimensions of 7.5 x 7.5 x 5.7 mm, final dimensions of 6 x 6 x 4.5 mm	(Ultralux, Dabi Atlante; Ribeirão Preto, SP, Brazil) for 40 s.		
Manziuc DDS et al. (2019)	Assess the effect of material, thickness and glazing upon the color, translucency, and roughness of monolithic zirconia	IPS e.maxZirCAD/MT (Ivoclar Vivadent SG, Schann,Liechtenstein) Katana/HT (Kuraray Noritake Dental Inc) Vita YZ/HT (VITA Zahnfabrik, Germany) Cercon/HT (Dentsply Sirona)	10 mm diameter; 0.8, 1.5, and 2 mm thickness, of shade A1	Spectrophotometer (VITA Easyshade Advance 4.0, VITA Zahnfabrik, Germany), black background (L* = 18.53, a*= 0.17, b*= –2.41), opaque white background, (L*= 93.49, a*= 3.37, b*= –10.90)	ZirCAD/MT ΔE00 ranged between 1.72 and 3.00; for VitaYZ ΔE00 = 1.95-2.75; for Katana ΔE00 = 2.19-3.33; for Cercon ΔE00 = 2.78-3.20)	
De Carvalho Almança Lopes et al. (2015)	Check the degree of conversion (DC), Vickers microhardness (VH) and elastic modulus (E) of resin cements cured through different ceramic systems	Ivoclar Vivadent, Schaan, Liechtenstein) Polycrystaline zirconia ceramic (Lava Al.-Ceramic System; 3M ESPE, Seefeld, Bavaria, Germany)	1.5 mm thick, 10 mm in diameter and Vita shade A2 color	The light curing through the ceramic discs for 40 s and 120 s, light-curing unit (Optilux 501; Kerr) at 650 mW/cm²	Zirconia + feldspathic 75 mW/cm² 11.5%	Zirconia + Feldspathic: Al.cem 87.5% Variolink II 63.0% RelyX U200 70.6% Multilink 56.7%

AUTHOR (YEAR)	PURPOSE	ZIRCONIA TYPE	THICKNESS	LIGHT CURING IRRADIATION	LIGHT-CURING IRRADIATION THROUGH THE ZIRCONIA	DEGREE OF CONVERSION (%) OR MICRO-HARDNESS (HV OR HK)
Erdelt et al. (2019)	Analyze the relationship between thickness and translucency	KATANA Zirconia Super Translucent Multi-Layered Disk and Zirconia Ultra Translucent Multi-Layered Disk and Zirconia Ultra Translucent	1.3, 1.0, 0.7, and 0.4 mm. VITA shade A2	A spectrophotometer (Lambda 35 Perkin Elmer Perkin Elmer Inc.) wavelengths (from 400 to 700 nm, intervals of 2 nm).	0.4mm: STML-EL 49.21 ±0.77cA STML-TL1 46.91 ±0.63bA STML-TL2 42.10 ±0.60aA STML-BL 42.11 ±0.55aA UTML-EL 54.88 ±0.85cA UTML-TL1 52.61 ±0.50dA UTML-TL2 52.19 ±1.08dA UTML-BL 52.71 ±1.10dA 0.7mm:STML-EL 37.99 ±0.77cB STML-TL1 35.63 ±0.44bB STML-TL2 33.94 ±1.06aB STML-BL 33.64 ±0.74aB UTML-EL 50.25 ±1.38fB UTML-TL1 45.67 ±0.67eB UTML-TL2 44.32 ±0.30eB UTML-BL 42.41 ±0.59dB 1.0mm:STML-EL 33.94 ±0.38dC STML-TL1 31.12 ±0.64cC STML-TL2 29.33 ±0.14aC STML-BL 28.17 ±0.40aC UTML-EL 40.23 ±0.76hC UTML-TL1 39.20 ±0.59gC UTML-TL2 38.28 ±0.38fC UTML-BL 35.76 ±0.47eC 1.3mm: STML-EL 31.32 ±0.36cD STML-TL1 28.22 ±0.51bD STML-TL2 25.70 ±0.74aD STML-BL 25.76 ±0.54aD UTML-EL 37.62 ±0.40fD UTML-TL1 35.52 ±0.43eD UTML-TL2 34.08 ±0.43dD UTML-BL 30.99 ±0.31cD 1.6mm: STML-EL 28.73 ± 0.62cE STML-TL1 24.52 ± 1.73bE STML-TL2 22.93 ± 1.08bE STML-BL 21.36 ± 1.27aE UTML-EL 33.71 ± 0.34eE UTML-TL1 31.83 ± 0.29dE UTML-TL2 30.48 ± 0.40dE UTML-BL 28.06 ± 0.52cE	

AUTHOR (YEAR)	PURPOSE	ZIRCONIA TYPE	THICKNESS	LIGHT CURING IRRADIATION	LIGHT-CURING IRRADIATION THROUGH THE ZIRCONIA	DEGREE OF CONVERSION (%) OR MICRO-HARDNESS (HV OR HK)
Rodrigo Othávio Assunção Souza et al. (2018)	Evaluate the performance of ultra-thin monolithic zirconia veneers adhesively luted to enamel surfaces after minimal invasive preparations	Translucent zirconia (Y-TZP) Prettau Anterior, Zirkonzahn, Gais, Switzerland)	0.3 mm	40 seconds on each veneer surface (Radii Cal, SDI Limited, Victoria, Australia; 1000 mW/cm^2).		(UT) zirconia (500 to 800 MPa)
Seok-Hwan Cho et al. (2015)	Evaluated the effects of ceramic veneer thicknesses on the polymerization of two different resin cements	ceramic material (e.max Press; Ivoclar Vivadent) from a Low Translucency (LT) ingot (A1 shade)	0.3 mm, 0.6 mm, 0.9 mm, and 1.2 mm	LED curing light (Demi Plus LED; Kerr) 15 s (0 mm) 900mW/cm^2 0.3mm 585mW/cm^2 0.6 mm 566mW/cm^2 0.9 mm 558mW/cm^2 1.2mm 549mW/cm^2		DC 0.3mm 34.8 ±12.8a 0,6mm 32.7 ± 6.4a 0,9mm 28.5 ±8.8a 1,2mm 14.0 ± 7.4b Microhardness (kg/mm2) 0,3mm 18.2 ± 4.4b 0,6mm 15.4 ± 2.5b 0,9mm 13.2 ± 5.3b.c 1,2mm 9.6 ± 1.8

The major findings can be drawn as follow:

- The amount of light that passes through the zirconia structure depends on the translucency, microstructure, zirconia composition, thickness, porosity, and manufacturing technique[2,4,5,12] . Regarding the chemical composition, the tetragonal zirconia polycrystal (YTZP) stabilized with yttria (Y_2O_3) is quite opaque although the translucency can be adjusted by the yttria content[7].

- The thickness was the major parameter that affect the light transmittance. The highest light transmittance was recorded through the zirconia (Ceramil Zi,DD BIO ZM translucident, ZENOstar, Prettau,Ceramill Zolid, InCoris TZI) thickness up to 0.5 mm although the light transmittance decreased as the increase in zirconia thickness from 0.5 up to 2mm[9,12].

- The degree of conversion of the resin-matrix cement was negatively affected by the decrease in light transmittance through the zirconia [1,4,6,16]. For example, at 5 min after curing, the DC ranged from 40% to 50% and increased gradually to 70% to 80% one week after curing.

- A proper degree of conversion of the resin-matrix cement can be achieved on a proper intensity of the light-curing unit source at 1400 mW/cm^2 and exposure time ranging from 20 up to 120 s[5,16]. For instance, 1400 mW/cm^2 light emission for 20 s generates ~28 J/cm^2 energy.

- Also, the wavelength of the light-curing unit should be at the blue light range (360–540 nm) to stimulate all the potential photoinitiators in the resin-matrix phase since current resin-matrix cements can have different photoinitiator molecules[5,14].

4. DISCUSSION

4.1 Zirconia

Since the introduction of ceramic materials in dentistry, unprecedent aesthetic outcomes have been accomplished to satisfy the demands of patients. Single- and multi-unit restorations such as crowns, veneers or infra-structures can be produced by ceramics and glass-ceramic materials(7,14,15). Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) is well-known in the restorative dentistry field due to its mechanical properties such as flexural strength ranging from 900 up to 1200 MPa, fracture toughness at around 9-10 MPa·$m^{1}/_{2}$, and elastic modulus at approximately 210 GPa(3,6). The first type of ordinary zirconia was stabilized with 3mol% yttria (3Y-TZP) although the opacity is too high to mimic the teeth enamel structure. Translucent ceramic or glass-ceramics are required to mimic the optical properties of teeth enamel.(1,14,15)

Changes in the chemical composition of zirconia resulted in high translucency zirconia that has given the capability to manufacture the entire prosthetic crown structure. In this way, the percentage of yttria has been increased from 5 up to 8% Y_2O_3 and therefore the cubic crystals were added ranging from 20 up to 50% in the microstructure, that resulted in the translucency increase but some disadvantages are related to the mechanical properties(14,17). For instance, Y-TZP stabilized through yttria (Y_2O_3) has excellent mechanical properties (up to 1200 MPa depending on type, fracture toughness at around 9-10 MPa·$m^{1}/_{2}$, and elastic modulus at approximately 210 GPa) as mentioned above(3,6,15). Another way to increase the zirconia translucency was to decrease the amount of alumina (0.05%) and increasing the content of lanthanum oxide (0.2%). Also, the size of crystals was decreased below 80 nm to enhance the translucence of the zirconia.(12,14,18)

Computer-aid design and manufacturing (CAD-CAM) has gained popularity over the recent years and has improved the manufacturing of prosthetic structures. Such processing involves scanning teeth structures or models to create a CAD file (ex. STL file), which is then followed to design the prosthetic structures by using a compatible software[9,11,15]. After digital designing, the robotic milling process, known as CAM, is carried out on pre-sintered zirconia. The milled structure comes out from the CAM machine with dimensions 20-25% larger than the final required dimensions. A shrinkage of the zirconia takes place during sintering from 1360-1530°C to reach the required dimensions and properties[9,11].

The selection of the zirconia type is critical to the recommended translucency for enamel or dentin. Also, porosity, grain size, and thickness control the dispersion and absorption of light during the polymerization of prosthetic cementation[12,14,16]. The zirconia type for veneers might be produced from tetragonal zirconia partially stabilized by yttria (Y-TZP) with high crystalline-content; for example (Prettau Anterior, Zirkonzahn, Gais, Switzerland), to provide translucency, while prosthetic infra-structures can be produced from, Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP)[1,5]. Regarding the thickness, veneers can reveal thickness between 0.3 up to 1,2 mm and zirconia crown thickness can vary from 0,5 up to 2mm , while the zirconia infrastructure ca reveal thickness at around ≤4 mm.[5,6,8]

4.2. Thickness and translucency of zirconia prosthetics

The selected studies have shown a significant influence of the veneer thickness on the light transmission through the ceramic and polymerization of the resin-matrix cement, as seen in (Table 1). The minimum ceramic thickness for monolithic indirect restorations was recorded at around 0.2-0.3 mm although the risks of fracture are higher for glass-ceramics when compared to zirconia[8,13]. Ceramic veneers can be manufactured with thickness ranging from approximately 0.2 up to 1.2 mm and therefore the light transmission required for the degree of conversion of the resin-matrix can also vary. The increased thickness (1.5-2 mm) of zirconia monolithic crowns negatively affects the polymerization and properties of the underlying resin cement[3,9] (Figure 2). Thus, different results are reported depending on the thickness, microstructure, ceramic, and resin-matrix cement.

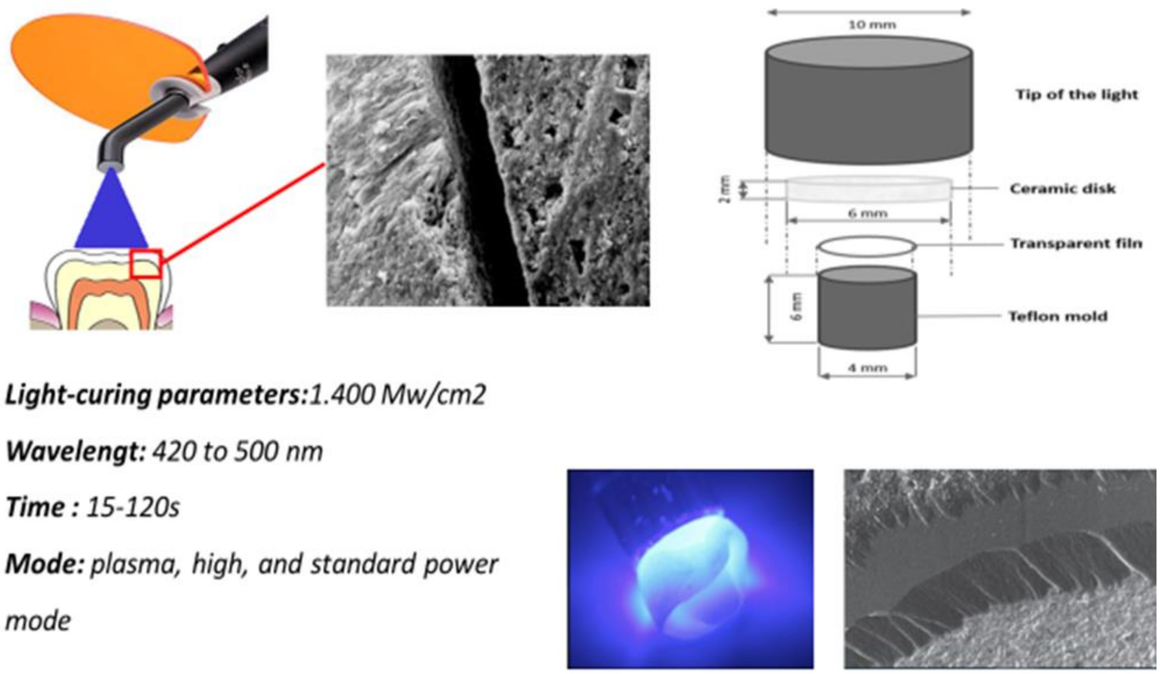

Figure 2. Schemes of photopolymerization through a crown and dentine crown interface and *in vitro* preparation.

A previous study reported a decrease of light curing transmission source from 900 mW/cm^2 (without veneer) down to 585 mW/cm^2 through 0.2 mm polycrystalline ceramic and to 549 mW/cm^2 through 1.2 mm ceramic polycrystalline ceramic[10,13]. In fact, dual resin cement showed significant differences in polymerization under polycrystalline ceramic thickness of 1.2 mm when compared to veneer thicknesses ranging from 0.3 to 0.9 mm.[8,13] Regarding a proper light wavelength, the light transmission intensity and time are dominant factors to establish the threshold energy for the degree of conversion of monomers in the organic matrix of the resin cements[1,4,5] .

A high degree of conversion can be accomplished at optimum light-curing conditions that involves the thickness of the zirconia prosthetics. The polymerization and properties of the resin-matrix cements are dependent on the degree of conversion of the methacrylate-based monomers[1,16]. However, a significant residual unsaturation of the polymeric chain takes place and the degree of conversion can vary from 55 up to 75% under standard light irradiation: 430-480 nm wavelength and a power density at 1200 mW/cm^2. Thus, the degree of conversion depends on the energy absorbed by the resin-matrix cement from the light irradiation[1,2,5] .

A low degree of conversion results in detrimental effects to the properties of resin-matrix cements and on the tooth-cement-zirconia interface[12,17] . Resin-matrix cements have been evaluated by several factors concerning physical properties like hardness, elastic modulus, and strength[9,12] . Most studies analyzed hardness of light-, dual-, and self-cured resin-matrix cements since the reliability of micro-hardness measurement (Table 1). Since the polymerization occurs from light irradiation, light-cured and dual-cured resin cements are directly affected by the thickness of the zirconia restoration[13,16].

However, the polymerization of the dual-cured resin cements starts from the cementation due to the chemically activation that counterbalance the ineffective light activation[10,13] . In the case of thick (>1.5-2 mm) zirconia restoration, dual- or self-cured cements are recommended once the light transmission decreases through the structural material although it depends on the microstructure of the zirconia. However, the color stability of dual-curing resin cement is inferior to that of light-curing cement due to the oxidation of tertiary aromatic amines bonded to benzoyl peroxide which is known as a polymerization initiator(5,8,13,18). Also, incomplete polymerization of resin cement can lead to color instability, monomer-related toxicity, decreased bond strength, postoperative sensitivity, increased risk of nanoleakage, and secondary caries.(5,12,18). In this way, the handling and selection of resin-matrix cements becomes a key factor of long term clinical success on zirconia restorations.(4,15).

An optical state between complete opacity and transparency named translucency is the essential factor in proper selection of ceramic materials to achieve required aesthetic outcomes. Translucency of restorative ceramics depends on the following aspects: light scattering and absorption, grain size and thickness of ceramics, oxide additives, density, porosity and, sintering process.(1,16) Absolute translucency can be measured by the percentage of the transmitted light. The "relative translucency" is recorded using either the contrast ratio or the translucency parameter (TP), which are calculated as difference in luminance and respectively, color, when the material is assessed upon ideal black vs white background.(1,8) Opaque materials reveal high TP values.

The contrast ratio is defined as the illuminance ratio (Y) of the test material when placed over a black background (Yb) or a white background (Yw).(12,13) However, ideal white and black backgrounds are not commonly used for translucency measurements, due to their availability.(1) A relative translucency parameter (RTP) must be considered when optical measurements are carried out on non-ideal backgrounds and when optical properties of the material are not homogeneous throughout its thickness.(1,3) The values of this parameter are relative to the color of the white and black backgrounds used for measurements (14,3).

Zirconia is less translucent when compared to glass-ceramics considering the microstructure and thickness, as see in Table 1. The translucency of zirconia can be improved by reducing residual porosity and also by forming nanometric features in the microstructure once the in-line transmittance of 50% at the visible wavelength range is expected for grain sizes <40 nm.[9] Additives for zirconia densification such as alumina decrease the zirconia translucency and therefore the chemical composition also play a role on the optical properties of the zirconia.[9,11,3] Monolithic Y-TZP materials with high translucency have been improved for use in the anterior tooth region as an alternative to glass-ceramics such as lithium disilicate reinforced or zirconium-lithium silicate glass-ceramics. High-translucency zirconia is manufactured with an increased yttria content (>8mol%) to achieve tetragonal phase stabilization and increased cubic phase.[5,18]

The amount of light emission that is absorbed, reflected, and transmitted depends on the volume of zirconia crystals within the matrix, their chemical nature, and their size compared to the incident light wavelength.[4,8,12] The translucency of ceramics including zirconia is largely dependent on light scattering and thickness.[8,2] Zirconia appears opaque when the majority of light passing through a ceramic is intensely scattered and diffusely reflected while the material can be translucent when only part of the light is scattered and most is diffusely transmitted.[13,15] In clinical situations, zirconia-based restorations with various thicknesses are required, depending on the different patient-related conditions[11]. Therefore, an accurate knowledge of the relationship between the translucency and thickness of restorative materials is crucial to improving the esthetic zirconia outcomes.[1]

5.CONCLUSIONS

This scoping review reported previous findings regarding the effect of the thickness and microstructure of zirconia on the light transmission for the activation of the resin-matrix cements. Within the limitations of the selected studies, the following conclusions can be drawn:

- The thickness of the zirconia-based veneer or restoration negatively affected the light transmitted to the resin-matrix cement. For instance, a light transmittance of around 40 and 50% was achieved on 1mm-thick ceramic while the light transmittance of 20-30% is recorded for 2mm-thick ceramics;
- The zirconia microstructure also play an important role on the light transmission once the polycrystalline structure can vary depending on the chemical composition and sintering of the zirconia structure. Different zirconia brands reveal different translucency, which is strongly influenced by the thickness of the material. Therefore, zirconia materials such as Y-TZP containing lower amounts of alumina showed higher transmittance;
- As a consequence, low light transmission resulted in a lower cure depth and degree of conversion of the resin-matrix cements. In clinical applications, the light-curing parameters should also be controlled regarding the thickness and microstructure of zirconia structures. For instance, the light-curing intensity and time should be increased for thick and opaque zirconia;
- Dual polymerization of resin-matrix cements is recommended since the light-curing unit and parameters might have limitations regarding and thickness and microstructure of the zirconia structures. Knowledge on visible and blue light could help clinicians to individually adapt the light curing parameters to the selected materials. Also, the light-curing unit can have different light sources for several resin-matrix cements and might be useful for thick zirconia structures.

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