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THE INFLUENCE OF ZIRCONIA VENEER THICKNESS ON THE CONVERSION DEGREE OF RESIN-MATRIX CEMENTS.

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DECLARAÇÃO DE ORIGINALIDADE

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Gandra, 26 de setembro de 2019

O Orientador

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RESUMO

O objetivo deste estudo foi realizar uma revisão de literatura integrativa sobre a influência da espessura de facetas cerâmicas no grau de conversão dos cimentos resinosos. Uma pesquisa eletrônica foi realizada na base de dados de publicações científicas PUBMED usando a combinação dos seguintes termos científicos: *zirconia, thickness, veneer, conversion degree, resin cement, light curing* e *polymerization*. A pesquisa identificou 163 estudos, dos quais 21 foram considerados relevantes para este estudo. Esses estudos forneceram dados importantes levando em consideração a espessura da faceta, estrutura do material e tipo de cimento resinoso. Os estudos reportam uma diminuição significativa da transmissão de luz através do material quando a espessura da faceta de zircônia aumenta de 0.1 para 1.5 mm o que afeta negativamente a polimerização do cimento resinoso. A microestrutura da zircônia e do cimento resinoso associada a uma baixa translucidez também prejudica a irradiação do cimento resinoso. No entanto, materiais mais translúcidos são produzidos para potencializar a polimerização do cimento resinoso.

O aumento da espessura das facetas de zircônia é um fator preponderante relacionado a diminuição do grau de conversão dos cimentos resinosos. Entretanto, a microestrutura da faceta, tipo de cimento resinoso e o modo de polimerização podem ser ajustados para potencializar a polimerização dos cimentos resinosos.

PALAVRAS-CHAVE

Zircônia, espessura, veneer, translucidez, cimento resinoso, polimerização, grau de conversão.

ABSTRACT

The aim of this study was to conduct an integrative review on the influence of the ceramic veneer thickness on the conversion degree of resin-matrix cements. An electronic search was performed on PUBMED using a combination of the following search items: zirconia, thickness, veneer, conversion degree, resin cement, ligh curing, and polymerization. The research identified 163 studies, of which 21 were considered relevant for this study. Such studies provided significant data taking into consideration the zirconia thickness, microstructure, and type of resin-matrix cement. Findings were reported on an increase in the zirconia veneer thickness from 0.1 up to 1.5 mm that resulted in a decrease in the light irradiation through the veneer material towards to the resin-matrix cement. Also, the microstructure associated to a low translucency of zirconia veneer and resin-matrix cement negatively affected the conversion degree of the resin cement. However, those parameters can be adjusted to improve the polymerization of the resin-matrix cement.

The increase in zirconia veneer thickness is a key factor related to the decrease in the conversion degree of resin-matrix cements. However, the veneer microstructure, resin-matrix cement type, polymerization mode can be improved to improve the light-curing of resin-matrix cements.

KEYWORDS

Zirconia, thickness, veneer, translucency, resin cement, polymerization, conversion degree

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CHAPTER I: The influence of zirconia veneer thickness on the conversion degree of resin-matrix cements.

INTRODUCTION

Recently, the demand for aesthetics has led to the development of high strength materials such as zirconia-based structures for oral rehabilitation. Clinical cases with zirconia-based veneers have been reported in literature although failures can occur by veneer chipping or low adhesion to the teeth structures.[1-4] The ceramic thickness, microstructure, and the resin-matrix cement have an important role on the light curing, translucency, and color of the restoration.[5,6] A low degree of conversion of the resin-matrix cement is dependent on the cement properties itself, ceramic veneer thickness, and polymerization procedure.[7-9]

In dentistry, zirconia-based materials often contain zirconium dioxide named zirconia and 3-7% mol yttria in the chemical composition to maintain the tetragonal phase that determine the mechanical properties of the prosthetic structures.[10-12] The first generation of yttria-stabilized tetragonal zirconia polycrystal (YTZP) with 3-5% yttria has a three-point bending strength of 900 ±130 MPa, fracture toughness at 9 ±0.34 $MPa.m^{1/2}$, and elastic modulus of around 240 ±9.5 GPa.[13,14] However, the polycrystalline microstructure of the zirconia veneer and the increase in thickness negatively affect the light-curing of the resin-matrix cement.[13,15,16]

Over the years, several types of resin-matrix cement materials have been developed for the adhesion of ceramics and therefore methacrylate-based cements are the first choice material for joining dental structures and ceramic restorations. The chemical composition of resin-matrix cements involves the presence of Bis-GMA, TEGDMA, UDMA embedding inorganic fillers such as colloidal silica, ytterbium, or barium glass.[17,18] The resin-matrix composites possess the following properties which are important for cementing ceramic veneers: low solubility, translucency, flowability, easy handling, and elasticity.[13,17,19] Also, the solubility of the resin-matrix cement is lower than those recorded for conventional cements that promote a long-term sealing at the marginal region of the restoration.[13, 17] Regarding the polymerization, there are three types of resin-matrix cements: light-curing, self-curing, and dual-curing.[13] Light-curing and dual-curing methods are used for veneer adhesion with resin-matrix cements and therefore the light-curing method has the main advantage on the working time for cementation and removal of remnant cement at the veneer margins. Nevertheless, light-curing procedure cannot guarantee a high degree of conversion of the resin-matrix cement considering other factors such as veneer type and thickness, type of resin-matrix cement, and polymerization procedure.[17, 20, 21] On the other hand, the dual-cure resin-matrix cements contain a photoinitiator and ordinary compounds to induce the self-curing although that can reveal a low color stability of the cement depending on the chemical composition.[13] The major problem of having an inadequate polymerization is the low degree of conversion leading to a decrease in physical properties and color stability.[7, 13]

The aim of the present study was to conduct a scoping review of the literature on the influence of the veneer zirconia on the degree of conversion of the resin-matrix cements. It was hypothesized that the polymerization of the resin-matrix cement can be affected by the thickness and microstructure of zirconia veneers.

METHOD

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 "resin cement" OR ¨adhesive¨ AND "degree of conversion" OR "polymerization" OR "light-curing". The inclusion criteria involved articles published in the English language up to February 2019, reporting the influence of ceramic veneer thickness on the degree of conversion of resin cements. Two of the authors (JCMS, CMTZ) independently analyzed the titles and abstracts of potentially relevant articles. Selected articles were individually read and evaluated concerning the purpose of this study. The following factors were retrieved for this review: author names, journal, publication year, purpose, type of resin cement, thickness of zirconia veneer, light curing procedures, degree of conversion of the resin cement, physical properties.

RESULTS

The literature search identified a total of 163 articles in PubMed, as shown in Fig. 1. Duplicates were removed and then titles and abstracts of 137 articles were independently evaluated by two authors. A number of 114 articles were excluded because they did not meet the inclusion criteria. The remaining 23 potentially relevant studies were then evaluated (Fig. 1). Of those studies, 2 were excluded because they did not provide comprehensive data considering the purpose of the present study. Thus 21 studies were included in this review.[7, 13, 16, 22-39]

Of the 21 studies selected, 9 (42.9%) investigated the light-curing effect while five other articles (23.8%) evaluated the ceramic translucency. Three studies (14.3%) evaluated the conversion degree of the resin-matrix cement and then four articles (19%) assessed the veneer thickness. The retrieved data on the resin-matrix cement, zirconia veneer thickness, the light curing, conversion degree, and microhardness are given in Table 1. The major findings are drawn as follow:

- There is a list of factors that influence the optical characteristics of the zirconia veneer, such as: translucency, irradiation energy, veneer thickness, and ceramic brand. Thus, fully stabilized zirconia (FSZ) is more translucent than partially stabilized zirconia (PSZ) .[35]
- The translucency of the restoration is affected by the zirconia thickness and by the resin-matrix cement. A high translucency is achieved within thin zirconia veneer associated with translucent zirconia and resin-matrix cement. A lower light irradiance was reported in colored zirconia veneer than that in translucent zirconia veneer [16, 28-30]
- The degree of conversion of the resin-matrix cements is strongly affected by the polymerization mode and the zirconia thickness. Thus, an increase in veneer thickness from 0.1 mm (ultra-thin veneer) up to 1.5 mm decrease the light transmission through the zirconia to the resin-matrix cement causing a negative effect on the degree of conversion of the resin-matrix cement.[24-26]
- The highest degree of conversion was recorded for dual-cure cements as a function of the polymerization reaction of the resin-matrix cement.[24] A proper degree of conversion of the dual curing resin cements can be achieved

through ceramic veneers with 1mm thickness on 1000 mW/cm^2 irradiation for 60 s. [38] Authors recommend the use of dual cements but with a lower light sensitivity. [37]

- The decrease in microhardness values recorded on the resin-matrix cement was resultant from the low degree of conversion due to an increase in veneer thickness.[7,13, 27]

DISCUSSION

4. 1. Zirconia veneers

YTZP has been used to manufacture prosthetic structures such as aesthetic veneers and single-unit (crown) or multi-unit prostheses due to their physicochemical properties.[11, 12, 15] The facture toughness of YTZP is around 9-10 MPa.m$^{1/2}$ while the 3-point bending strength is ranging from 900 up to 1200 MPa.[40, 41] However, the Y-TZP polycrystalline microstructure results in a low translucency and therefore, the thickness of the material affect the curing process of resin-matrix cements. Prior the cementation, Y-TZP inner surface is modified by airborne abrasion (grit-blasting process) with alumina (Al_2O_3) particles followed by silica (SiO_2) particles.[42] Also, the application of a glass-ceramic thin layer (liner) can be an alternative approach to provide a silica-based coating which can be conditioned by 9% hydrofluoric acid (HF).[15, 42] However, the increase in roughness can also act as factor of light diffraction depending on roughness magnitude.

Regarding the low translucency and properties of YTZP, the thickness can play a key role on the clinical success of prosthetic restoration concerning cementation, aesthetics, and mechanical performance. Previous studies evaluated the polymerization of the resin cement through different Y-TZP specimens, as follow: 0.5-3, 0.6-1.0, 1.5, and 0.5-1.5 mm. The highest mean values of microhardness and degree of conversion were recorded for 0.5-1.0 mm YTZP thickness, as seen in Table 1. [25,28, 30-32]

A previous study reported 46.5% contrast ratio and 8.6% higher translucency for 0.3 mm Y-TZP veneer when compared to 0.5 mm YTZP veneer.[40] The analyses were performed with a spectrophotometer at the middle and cervical regions across the veneer. The values recorded for contrast ratio and translucency were acceptable at the body region although there was a bias of results for the cervical region. Another previous study reported a negative effect of the Y-TZP thickness on the polymerization of resin-matrix cements [31] that was related to an inadequate irradiance of the light source. On 1.65 mm veneers, the degree of conversion of the resin-matrix cement was significantly low when the light irradiation was below 300 $mW.cm^{-2}$. However, the threshold thickness of Y-TZP veneer was not determined.[31] Additionally, monolithic Y-TZP provided a lower light transmission value compared to other ceramic materials like lithium disilicate reinforced glass-ceramic.[43] The findings were corroborated by another previous study on the measurement of the light irradiance by Raman light spectrometry for 40 s regarding different thickness of zirconia veneers.[30] In fact, there is an inverse relationship between irradiating energy, translucency, and thickness, as illustrated in Figure 2.[27] A thick YTZP veneer negatively affects the light irradiance and polymerization of the resin-matrix cement and then decreases its conversion degree and color stability.[30,31]

In a previous study, the stress distribution in occlusal veneers was observed taking into account the veneer material and thickness and the cement thickness. The study consisted of 9 repetitions with different thicknesses for occlusal veneers (0.6, 1.2 and 1.8 mm) and cement (100, 200 and 300µm); An axial load of 600 N was applied to each sample. Results revealed high stress concentration through high translucency zirconia while hybrid ceramics provided the highest stress concentration at the resin-matrix cement.[36]

4.2. Resin-matrix cements

Considering the chemical similarity to resin-based composite materials, the chemical composition of resin-matrix cements involves several monomers and fillers, as shown in Table 1. The polymer-matrix of resin cements is composed of methacrylate monomers (40-60%wt) like Bis-GMA, UEDMA, and TEGDMA while the inorganic content is composed of colloidal silica, ytterbium fluoride, or barium glass fillers.[18,44] Taking into account the chemical composition, resin-matrix cements have properties quite similar to that of flowable resin composite materials such as: low solubility, translucency, and flowability.[13,19] The viscosity or flowability of the resin-matrix cements provide a mechanical interlocking to the primer-coated enamel and restorative surfaces. Also, the presence of 10-Methacryloyloxydecyl dihydrogen phosphate (10-MDP) promotes a physicochemical bonding to restorative ceramic surfaces. With the advances in adhesive dentistry, resin-matrix cements have become the first choice materials for the adhesion of ceramics to the teeth surfaces due to their physicochemical properties and clinical procedures.[7,34]

The chemical composition of the resin-cements also varies in the presence or not of photoinitiator compounds. Currently, dual curing resin-matrix cements are the most commonly materials used in fixed prostheses, since they have a polymerization activated by visible light at around 320-480 nm and by a chemical polymerization activation when two pastes are mixed.[26,45,46] The interaction between the benzoyl peroxide and tertiary amines (dimethyl-p-toluidine) is responsible for the chemical activation while photo-initiators such as canforquinone are stimulated by the light. The adequate properties of the materials are achieved by the accomplishment of the polymerization process that is mainly dependent on the chemical composition of the material and veneer material features.[25,27,33] Considering the chemical composition of the resin-matrix cements, most of the studies have correlate the chemical composition to the light irradiance time and intensity by infra-red spectroscopy analyses.[25, 27] A previous study reported a time-dependent effect of resin-matrix cements containing 10-MDP to the light curing procedure.[24,47] Also, the content and optical properties of the fillers can affect the light transmittance. On the other hand, a high filler content provides mechanical strength to the material.[26,31]

Kim et al.[24], Gultekim et al.[32], and Inokoshi et al.[30], showed that the transmittance of light decreases as the thickness of the ceramic veneer increases, generating an inadequate light transmission and poor conversion degree in the inner region of the prosthetic restoration.[26] Most of the studies assessed the mechanical behavior of the resin-matrix composites by microhardness assays and correlate the conversion degree of the material to hardness values, as seen in Table 1.[26,31]

4.3. Light-curing parameters

The light-curing process depends on the irradiance source, exposure time, and distance, and therefore on the resin-matrix cement.[47-49] The degree of conversion related to the light-curing is a key factor when selecting resin-matrix composite materials.[47] A low degree of conversion can be harmful to the physicochemical properties of the resin-matrix materials such as water sorption, solubility, strength, hardness, and optical properties.[25,51,52] The depth of the light-curing irradiance can be related to both resin-matrix composite thickness and distance from the light-curing handheld device tip.[7,25]

Previous studies reported an enhancement of the degree of conversion and microhardness of the resin-matrix composite when the irradiance time was increased.[13,26] High values of conversion degree and micro-hardness were recorded for resin-matrix cements after LED irradiation time ranging from 20 up to 120 s, as shown in Table 1. According to the results of similar studies, dual curing resin-matrix cements have revealed greater success when compared to self-curing or light curing cements.[26,54] The degree of conversion of four brands of resin-matrix cements has been evaluated by ATR/FTIR spectrometry, while the mechanical behavior has been evaluated by dynamic indentation test (e.g., microhardness test).[25] Lopes et al.[25], showed that the chemical curing has a low microhardness value and therefore the finding was also corroborated by another previous study.[16] The groups of resin-matrix cements that were light-cured through zirconia or lithium disilicate glass-ceramic veneers showed a higher degree of conversion than those for self-cured groups. [33] Therefore, a previous study revealed higher values of VHN (Vickers Hardness Number) for samples light-cured under LED source when compared to QTH source at higher depth of light-curing.[32]

An important aspect of the light-curing parameters is the power that the light source presents during polymerization procedure of the restorations. Irradiation power, wavelength, and curing time determine the energy for polymerization of the material. Another key factor to take into account is the photoinitiation molecules in the material, that generate the activation of free radicals.[54] Most of the studies carried out the light curing with a wavelength at 430-480 nm[13,16,27,28,32] although a few studies reported optimal values of degree of conversion and microhardness by using a wavelength at 500 nm (Fig. 2).[24,32] One study showed that the highest transmitted irradiance was achieved through a 0.5 mm ceramic thickness regardless of the type of material, although it was decreasing as the ceramic thickness increased. This study evaluated 35 samples of zirconia and 7 of glass ceramics (control), which were then stained with different shades (CL1, CL2, CL3 and CL4) but one sample remained unstained (CL0). [37]

Among the retrieved articles, the highest power values of the light curing sources recorded as regards the depth of the polymerization were at 1400 and 1500 nW/cm^2. [16,26] A previous study recommended a light intensity higher than 1000 nW/cm^2 for polymerization of resin-matrix cements.[54] However, adequate degree of conversion of dual curing resin-matrix cements was achieved under LED light-curing in a lower power of 718 nW/cm^2 .[33] A previous study showed that all groups had a higher degree of conversion, when they had been exposed to a longer irradiation time. Nevertheless, there was no significant difference for the irradiated groups with 1000 mW/cm^2 and 1500 mW/cm^2. On longer exposure time, an increase in temperature can be noted for 1000 mW/cm^2 when compared an irradiation of 500 mW/cm^2 that can lead unfavorable dentin sensitivity.[38] A previous study assessed the irradiation technique, polymerization time, and storage conditions by measuring the, Vickers hardness and the degree of conversion of resin-matrix cement. Findings revealed that proper mechanical properties can be achieved within a minimum irradiation time of 20 s.[39]

CONCLUSIONS

In the present review, relevant articles reported significant findings on the effect of the zirconia veneer thickness over the degree of conversion of resin-matrix cements. The main outcomes of the selected studies can be drawn as follow:

- The thickness of the zirconia veneers is determinant for an appropriate aesthetic result although that affect the polymerization of resin-matrix cements;

- Zirconia veneers with higher thickness can interfere within the light intensity to the resin-matrix cement decreasing the degree of conversion of the resin-matrix monomers. A low degree of conversion promotes a low chemical stability which can be detected by color instability and low microhardness values;
- Thin and ultra-thin zirconia veneers associated with translucent resin-matrix cements have achieved proper optical results for applications as aesthetic veneers;
- Further studies should be carried out concerning the chemical composition, thickness, and microstructure of zirconia-based materials. Also, surface modifications of the inner surface of zirconia veneer or glass-ceramic coating of the outer region can affect the light transmission through the ceramic material towards to resin-matrix cement and therefore those factors should be carefully evaluated in future studies.

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CHAPTER II: Relatórios de estágio

INTRODUÇÃO

O estágio de Medicina Dentaria é um período supervisionado por diferentes docentes, sendo composto por três:

1. Estágio Hospitalar
2. Estágio de Clínica Geral Dentária
3. Estágio de Saúde Oral Comunitária

Os estágios foram realizados no plano curricular do 5º ano do Mestrado Integrado que ocorre entre Fevereiro de 2018 até Fevereiro de 2019, tendo como principais objetivos:

i. Preparar o aluno, de forma a que este consiga aplicar na prática clínica todos os conhecimentos teóricos anteriormente aprendidos e estabelecer um correto diagnóstico de acordo com o caso em questão e saber encaminhar ao especialista certo.

ii. Tornar o aluno mais autónomo, mais ágil e mais eficiente no decorrer do ato clínico.

iii. Permitir que o aluno desenvolva com as diferentes populações.

RELATÓRIO DAS ATIVIDADES PRÁTICAS DAS DISCIPLINAS DE ESTÁGIO SUPERVISIONADO

1. Estágio saúde oral comunitária

O Estágio em Saúde Oral Comunitária teve lugar às quartas-feiras de manhã, das 9h às 12:30h, e foi supervisionado pelo Professor Doutor Paulo Rompante. Primeiramente foi definido um cronograma de atividades de acordo com o Programa Nacional de Promoção de Saúde Oral (PNPSO) para populações alvo tais como idosos, grávidas e crianças, com o intuito de implementar hábitos de saúde oral.
Numa segunda fase fomos uma vez por mês para o Estabelecimento Prisional de Paços de Ferreira e ao Hospital da Misericórdia onde pudemos realizar as atividades.

Na tabela 1 estão discriminados os atos clínicos como operador e assistente realizados no âmbito deste estágio.

Tabela ***1:*** *Atos clínicos efetuados durante o estágio de Saúde oral comunitária*

Ato clínico	**Operador**	**Assistente**	**Total**
Desntisteria	0	2	2
Endodontia	0	0	0
Exodontia	2	5	7
Destartarização	1	0	1
Triagem	0	0	0
Outros	1	1	2
Total	4	8	12

2. Estágio hospitalar

O estágio Hospitalar decorreu no Hospital Nossa Senhora da conceição-Centro Hospitalar São João, em Valongo. O primeiro semestre do ano teve início no dia 22 de fevereiro de 2018 e terminou o dia 5 de julho de 2018, foi realizado todas as quartas-feiras entre as 14h00 e as 17h00. Decorreu sob a supervisão da Professora Doutora Ana Manuela Salvaterra Azevedo. No segundo semestre foi a partir do dia 17 de setembro de 2018 até o 11 de março de 2019, sendo feito às segundas-feiras entre as 14h00 e as 17h00; com a supervisão do Professor Doutor Luís Monteiro. Este estágio me ajudou a ter a capacidade de lidar com vários tipos de situações.

Na tabela 2 estão discriminados os atos clínicos como operador e assistente realizados no âmbito deste estágio.

***Tabela 2**: Atos clínicos efetuados durante o estágio Hospitalar*

Ato clínico	Operador	Assistente	Total
Desntisteria	18	14	32
Endodontia	5	4	9
Exodontia	14	16	30
Destartarização	10	12	22
Triagem	1	6	7
Outros	3	2	5
Total	51	54	105

3. Estágio em clínica dental geral

O estágio em Clínica Geral Dentária é fundamental, foi realizado nas instalações da Unidade Nova Saúde em Gandra. O primeiro semestre do ano teve início no dia 23 de fevereiro de 2018 e terminou o dia 15 de junho de 2018, foi realizado todas as sextas-feiras entre as 19h00 e as 23h00. No segundo semestre foi a partir do dia 26 de setembro de 2018 até o 13 de fevereiro de 2019, sendo feito às quartas-feiras entre as 19h00 e as 23h00. Os atos clínicos foram supervisionados pelo Mestre João Baptista e Mestre Luís Santos e encontram-se descritos na tabela 3.

Tabela 3: *Atos clínicos efetuados durante o estágio Clínica geral*

Ato clínico	**Operador**	**Assistente**	**Total**
Desntisteria	8	11	19
Endodontia	2	6	8
Exodontia	3	1	4
Destartarização	1	2	3
Triagem	2	1	3
Outros	1	1	2
Total	17	22	39

ANEXOS

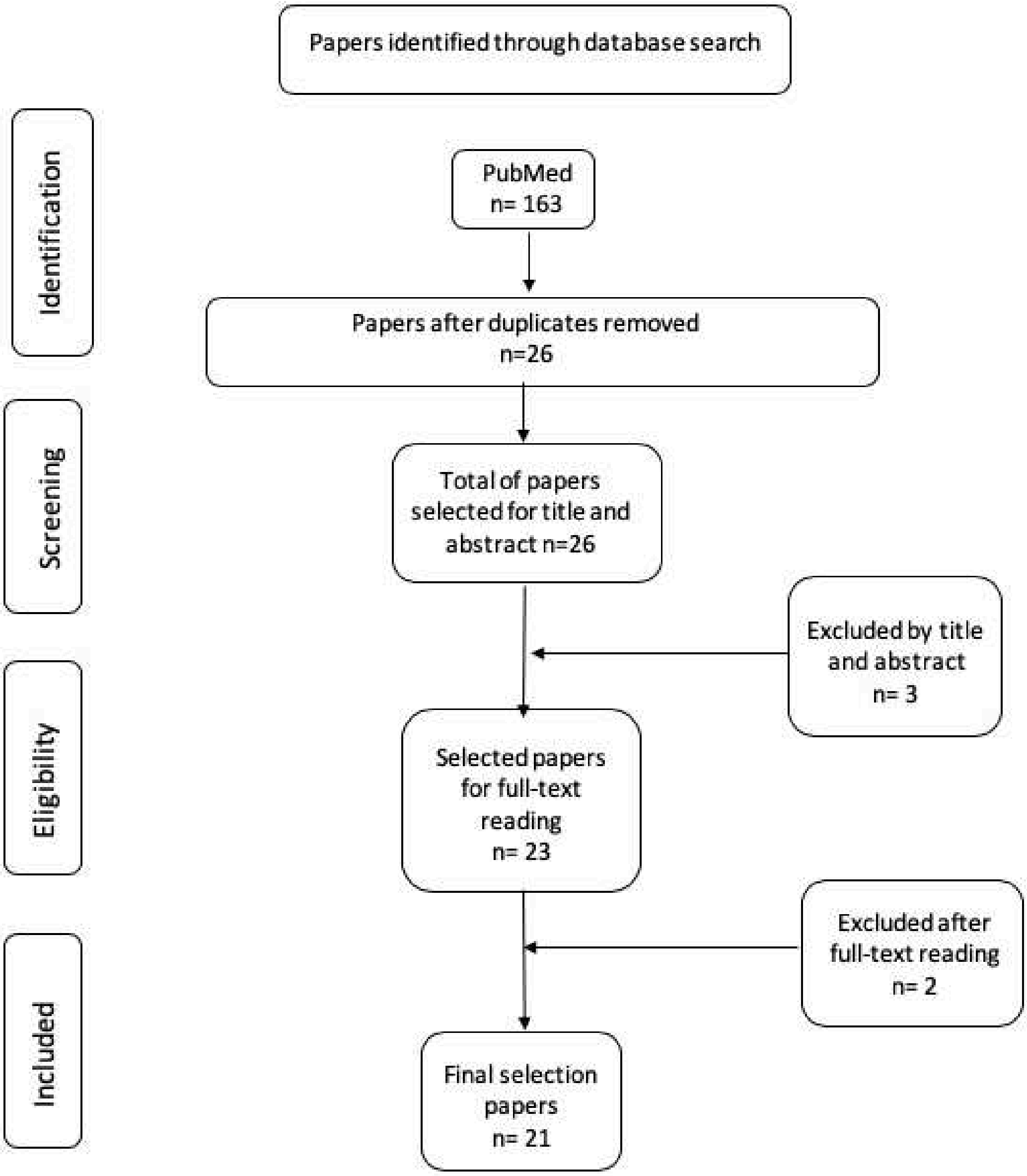

Figure 1. Flow diagram of the search strategy used in this study.

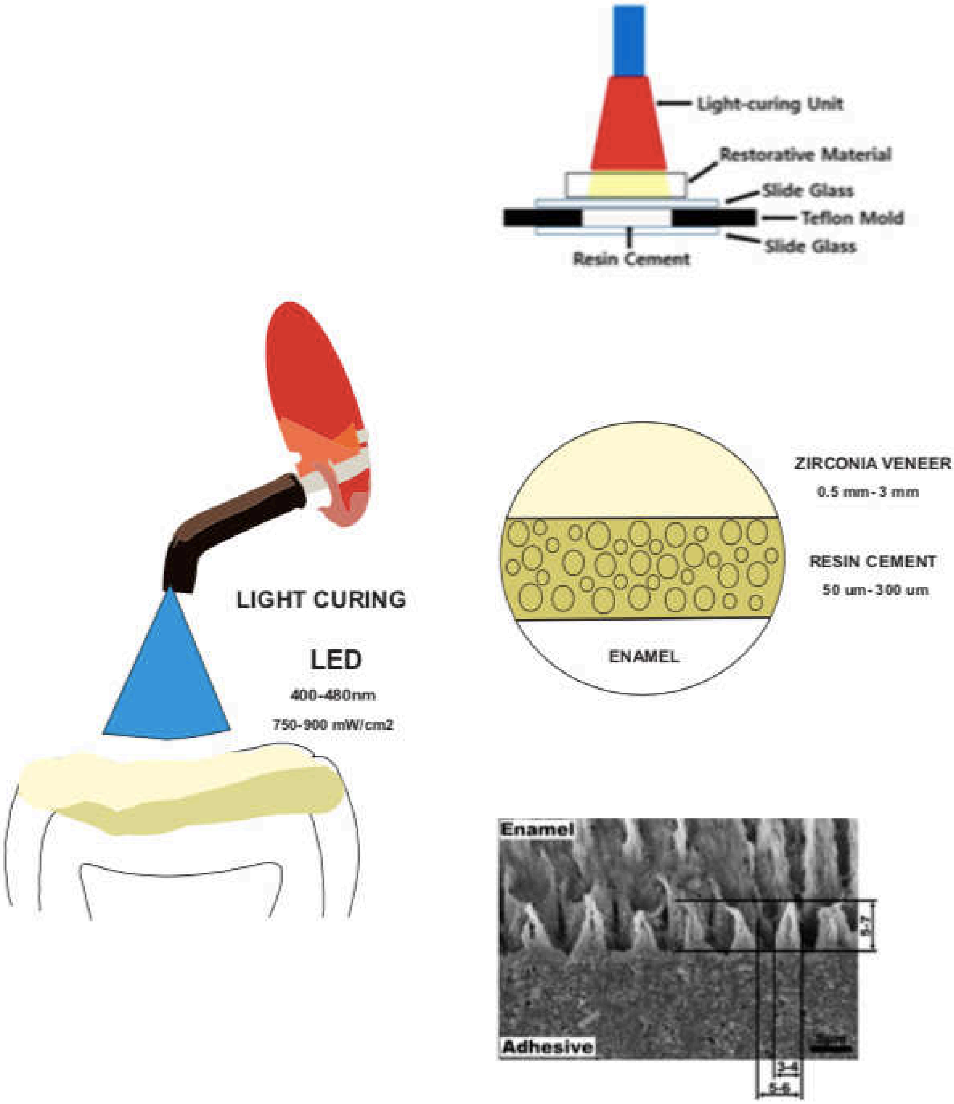

Figure 2. Schematic drawing

Table 1. Relevant data gathered from the retrieved studies.

Author (YEAR)	Purpose	Resin cement (chemical composition)	Zirconia Veneer thickness (mm)	Light curing	Degree of Conversion (%)	Microhardness (HV)
Turp et al., (2010)[7]	Investigation of the polymerization efficiency of dual-cured resin cement beneath different shades of zirconia-based feldspathic ceramic restorations.	10- MDP, DMA, Bis-MPEPP (25%); silanized barium glass (75%); Panavia F 2.0	1.2	Quartz tungsten halogen curing (Hilux 200) for 20 s; 600 mW/cm2	-	1M2: 65 59 55 53 2M2: 59 52 44 34 3M2: 55 43 35 29 4M2: 44 43 20 17 5M2: 41 28 25 18

Turp et al., (2014)[13]	Evaluation of the effect of thickness of zirconia on curing efficiency of resin cements.	10- MDP, DMA, Bis-MPEPP (25%); silanized barium glass (75%); Panavia F 2.0	G: 0.5 G1: 0.5 +0.5 porcelain G2: 1.0 +0.5 porcelain G3: 1.5 +0.5 porcelain	LED (Elipar S10, 3M, ESPE, Saint Paul, MN, USA) for 20 s, 430-480nm, 1200 W/cm2	55-75	G0: 69.95 62.67 53.15 G1: 65.26 58 49 G2: 62.8 54.15 43.64 G3: 52.1 49.33 39.41
		Bis-GMA, UDMA, TEGDMA; glass fillers; Bisco Duo-Link				G0: 66.05 56.12 48.15 G1: 58.43 48.29 43.47 G2: 55.18 44.78 39.23 G3: 47.78 39.37 29.68

Caprak et al., (2018)[16]	Evaluation of the influence of the translucency parameters (TPs) of current monolithic CAD/CAM blocks on the microhardness of light-cured or dual-cured resin cement.	Bis-GMA, UDMA, TEGDMA; glass fillers; Bisco Duo-Link	2.00	LED (HS-LED1500; Henry Schein, Ontario, Canada) for 40s; 1500 mW; 450-470 nm	-	Dual cure	Ligth cure
						G0:59.90 G1: 53.42 G0: 57.9 G1: 52.02 G0: 56.56 G1: 49.73 G0: 56.83 G1: 48.94	G0: 56.36 G1: 48.01 G0: 54.77 G1: 46.27 G0: 53.19 G1: 45.07 G0: 53.21 G1: 43.32
Bansal et al., (2016)[22]	The aim of the study is to evaluate the effect of ceramic type, thickness, and time of irradiation on degree of polymerization of dual-cure resin cement.	UDMA, TEGDMA, methacrylate; Dental glass; SoloCEM	2.0 3.0 4.0	Halogen curing light (Spectrum 800, Dentsply, Baar, Switzerland) 40, 60 and 80 s; 600mW/cm2	-	-	

Shiomuki et al., (2013)[23]	The study evaluated the effects of these factors on the degree of polymerization of dual-cure cement (Panavia F2.0) placed under a restoration: light transmission property of restoratives materials, distance from the directly irradiated surface, and elapsed time after light irradiation.	10- MDP, DMA, Bis-MPEPP (25%); silanized barium glass (75%); Panavia F 2.0	3	LED (G-Light) for 5 s	-	-
Kim et al., (2013)[24]	The aim of this Fourier transforms infrared (FTIR) spectroscopic study was to measure the degree of conversion (DC) of dual-cured resin cements light-irradiated through zirconia ceramic disks with different thicknesses using various light-curing methods.	10- MDP, DMA, Bis-MPEPP (25%); silanized barium glass (75%); Panavia F 2.0 Bis-GMA, UDMA, TEGDMA; glass fillers; Bisco Duo-Link	1.0 2.0 4.0	Elipar TriLight (standard mode); 750 mW/cm2; 400-515 nm. Bluephase G2 (high power mode) for 40 and 120 s; 1150 mW/cm2; 385-515 nm	-	-

Lopes et al., (2015)[25]	The aim of the study was to verify the degree of conversion (DC), Vickers microhardness (VH) and elastic modulus (E) of resin cements cured through different ceramic systems.	Bis-GMA, Bis-EMA, TEGDMA (35%); Barium alumo-silicate glass, silicon dioxide (66%); Allcem	1.5	Conventional Halogen light-curing (Optilux) for 120 s; 501-650 mW/cm2	-	G0: 74.4 G1: 71.1
		Bis-GMA, urethane dimethacrylate, and triethylene glycol dimethacrylate. (56.4%); Barium glass, ytterbium trifluoride, Ba-Al-fluorosilicate glass, and spheroid mixed oxide (43.6%); Variolink II				G0: 60.7 G1: 67.9
		Methacrylate monomers (28%); Silanated fillers, alkaline fillers. (72%); RelyX U200				G0: 70 G1: 76.2
		Bis-GMA, UDMA, Bis-EMA, HEMA (60.3%); Barium glass, ytterbium trifluoride, spheroid mixed oxide (39.7%); Multilink.				G0: 44 G1: 43.7

Alovisi et al., (2018)[26]	The aim of the in vitro study was to assess conversion degree (DC), micro-hardness (MH) and bond strength of two dual-curing resin cements employed under translucent monolithic zirconia irradiated with different time protocols.	Methacrylate monomers (57%); Silanated fillers Radiopaque alkaline fillers (43%); RelyX Ultimate	1	LED (Valo, Ultradent, South Jordan, UT, USA) for 0 s, 20 s and 120 s; 1400 mW/cm2	-	-
Sulaiman et al., (2015)[27]	Evaluation of the influence of material thickness on light irradiance, radiant exposure, and the degree of monomer conversion (DC) of 2 dual-polymerizing resin cements light-polymerized through different brands of monolithic zirconia.	Methacrylate monomers (57%); Silanated fillers (43%); RelyX Ultimate	0.5 1.0 1.50 2.00	LED (Elipar S10) for 20 s; 1200 mw/cm2; 430-480 nm.	63.1	-
		Bis-GMA, urethane dimethacrylate, and triethylene glycol dimethacrylate. (56.4%); Barium glass, ytterbium trifluoride, Ba-Al-fluorosilicate glass, and spheroid mixed oxide (43.6%); Variolink II		LED (Elipar S10) for 40 s; 1200 mw/cm2; 430-480 nm.	66	-

Malkondu et al., (2016)[28]	The purpose of the in vitro study was to evaluate color changes in terms of the perceptibility and acceptability of monolithic zirconia-and-cement combinations with 2 monolithic zirconia thicknesses and 3 types of cement. The translucency parameters of these combinations were also compared.	Methacrylate monomers (28%); Silanated fillers, alkaline fillers. (72%); RelyX U200 HEMA; Fluoro aluminosilicate glass; RelyX Luting	0.6 1.0	LED (Elipar S10, 3M ESPE) for 20 s; 1200 mW/cm2; 430-480 nm	-	-
Capa et al., (2017)[29]	Evaluation of the effect of the different color of resin cements and zirconia cores on the translucency parameter (TP) of the restoration that simulates the implant-supported fixed prosthesis using titanium base on the bottom.	Methacrylate monomers (57%); Silanated fillers Radiopaque alkaline fillers (43%); RelyX Ultimate Methacrylate monomers (28%); Silanated fillers, alkaline fillers. (72%); RelyX U200	0.5	Halogen curing light (Optilux 501, Kerr Corporation, Orange, CA, USA) for 40 s	-	-

Inokoshi et al., (2016)[30]	Assessment of the light irradiance (LI) delivered by two light-curing units and to measure the degree of conversion (DC) of three composite cements and one flowable composite when cured through zirconia or ceramic-veneered zirconia plates with different thicknesses.	Bis-GMA, TEG-DMA; Silanated barium glass filler; Clearfil esthetic cement	0..5 1.5	LED (G-Light Prima and SmartLite FOCUS) for 40 s;	-	-
		10- MDP, DMA, Bis-MPEPP (25%); silanized barium glass (75%); Panavia F 2.0				
		UDMA; Fluoro alumino silicate glass; G-CEM LinkAce				
		Bis-MEPP, TEG-DMA; Strontium glass; G-aenial Universal Flo				

Turp et al., (2018)[31]	Evaluation of the influence of anterior monolithic zirconia and lithium disilicate thickness on polymerization efficiency of dual-cure resin cements.	10- MDP, DMA, Bis-MPEPP (25%); silanized barium glass (75%); Panavia F 2.0	0.5 1.0 1.5 2.0 2.5 3.0	LED (Elipar S10, 3M, ESPE, Saint Paul, MN, USA) for 20s (Panavia F2.0 and RelyX U200) and 40s (DuoLink Universal)		G0: 139 131.3 118.9 98.9 G1: 135.17 127.13 115.39 99.93 G2: 133.67 125.07 114.49 94.03 G3: 130.33 123.98 112.89 90.85 G4: 129.77 122.25 84.26 64.56
		Bis-GMA, UDMA, TEGDMA (40%); glass fillers (60%); Bisco Duo-Link				G0: 89.2 82.5 77.5 74.6 G1: 86.2 80.13 74.92 73.78 G2: 82.57 77.03

						70.07 69.48 G3: 79.13 76.33 69.17 68.58 G4: 78.63 76.93 68.97 66.58 G5: 42.26 36.53 33,67 29.35 G6: 40.46 32.53 31.97 27.48
		Methacrylate monomers (28%); Silanated fillers, alkaline fillers. (72%); RelyX U200				G0: 76.2 75.2 73.6 71.4 G1: 78.98 74.5 68.50 68.60 G2: 73.48 70.59 67.20 66.40

						G3: 72.19 69.09 66.6 66.1 G4: 68.09 68.99 66.20 64.7 G5: 33 36.53 33.67 29.35 G6: 19.39 32.53 31.97 27.48	
Gültekin et al., (2015)[32]	The aim of the study was to evaluate the polymerization efficiency of dual-cure resin cement cured with two different light curing units under zirconia structures having differing thicknesses	10- MDP, DMA, Bis-MPEPP (25%); silanized barium glass (75%); Panavia F 2.0	Z: 0.5 Z1: 0.5 +0.5 Porcelain Z2: 1.0 +0.5 Porcelain Z3: 1.5+0.5 Porcelain	LED (Elipar S10, 3M ESPE, Seefeld, Germany) for 20 s (5 s rmp, 15 s full cure); 430-480 nm; 1200mW/cm2 QTH (Hilux 200, Benlioglu, Istanbul, Turkey) for 40 s (time in continuous mode); 410-500nm; 600mW/cm2	-	QTH Z:66.78 60.52 48.71 Z1:58.85 54.35 44.15 Z2:52.77 48.29 41.34 Z3:49.37 46.20 37.88	LED Z:69.95 62.67 53.15 Z1:65.26 58 49 Z2:62.80 54.15 43.64 Z3:52.10 49.33 39.41

Shim et al., (2017)[33]	The aim of the study was to investigate the polymerization mode of self-adhesive, dual-cured resin cements light-cured through overlying materials with different degree of translucency by measuring the degree of conversion (DC).	UDMA; Fluoro alumino silicate glass; G-CEM Link ACE Bis-GMA; Fluoro aluminio silicate glass, fumed silica, barium glass, ytterbium fluoride; Maxcem Elite Bis-GMA; Dental glass; BisCem	1	LED (Dr's Light; Good Doctors Co., Incheon, Korea) for 40 s; 718 mW/cm2	50-75	-
Valentino et al., (2010)[34]	The study investigated the influence of ceramic compositions on Knoop Hardness Number (KHN) immediately and 24 h after polymerization and the effect of activation modes on the KHN of a resin cement.	10- MDP, DMA, Bis-MPEPP (25%); silanized barium glass (75%); Panavia F 2.0	1.2	Quartz-tungsten-halogen light (3M ESPE) for 40 s; 650 mW/cm2	-	-