UNIVERSIDADE FEDERAL DE PERNAMBUCO
CENTRO DE CIÊNCIAS DA SAÚDE
PROGRAMA DE PÓS GRADUAÇÃO EM ODONTOLOGIA
MESTRADO EM ODONTOLOGIA
ÁREA DE CONCENTRAÇÃO EM CLÍNICA INTEGRADA

MARIA HELOÍSA MARTINS

O TEMPO DE FOTOPOLIMERIZAÇÃO INFLUENCIA NO GRAU DE CONVERSÃO DOS CIMENTOS RESINOSOS? UMA REVISÃO SISTEMÁTICA DE ESTUDOS *IN VITRO*

RECIFE
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Dissertação apresentada ao Programa de Pós-Graduação em Odontologia da Universidade Federal de Pernambuco, como requisito parcial para obtenção do título de Mestre em Odontologia. Área de concentração: Clínica Integrada.

Orientador (a): Prof.ª Drª Bruna de Carvalho Farias Vajgel

Coorientador (a): Prof.ª Drª Juliana R. Souto Maior Costa

RECIFE

2022

Catalogação na Fonte
Bibliotecário: Rodriggo Leopoldino Cavalcanti I, CRB4-1855

M386t Martins, Maria Heloísa.
O tempo de fotopolimerização influencia no grau de conversão dos cimentos resinosos? : uma revisão sistemática de estudos *in vitro* / Maria Heloísa Martins. – 2022.
83 f. : il. ; tab. ; 30 cm.

Orientadora : Bruna de Carvalho Farias Vajgel.
Coorientadora : Juliana Raposo Souto Maior Costa.
Dissertação (Mestrado) – Universidade Federal de Pernambuco. Centro de Ciências da Saúde. Programa de Pós-Graduação em Odontologia. Recife, 2022.

Inclui referências, apêndice e anexos.

1. Cimentos Dentários. 2. Polimerização. 3. Espectroscopia de Infravermelho com Transformada de Fourier. I. Vajgel, Bruna de Carvalho Farias (Orientadora). II. Raposo, Juliana Raposo Souto Maior (Coorientadora). III. Título.

617.6 CDD (23.ed.) UFPE (CCS2023-046)

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Aprovado em: 23/02/2022.

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AGRADECIMENTOS

Agradeço a Deus, por ser meu amparo, me dar forças e me guiar todos os dias da minha vida. Agradeço por sempre me mostrar que sou capaz de ir muito além do que imagino, e por segurar na minha mão em todos os desafios vividos, me ajudando a superá-los.

Aos meus pais, Jose e Messias, por serem meus grandes incentivadores. Obrigada por toda doação e por sempre me apoiarem a buscar o caminho do conhecimento e da educação. Agradeço por toda compreensão, cuidado e amor.

À minha irmã, Catharine, por estar presente de uma forma tão especial em minha vida, me encorajando e torcendo sempre por mim. Obrigada por viver comigo todos os meus desafios e sonhos.

À minha orientadora, Professora Bruna de Carvalho Farias Vajgel, por todos os ensinamentos, oportunidades, conselhos e pelas palavras amigas quando mais precisei. Agradeço por todo carinho e confiança depositada em mim e no meu trabalho. Muito obrigada por acreditar no meu potencial.

À professora Juliana R. Souto Maior Costa, pela coorientação desse trabalho, e a todos que fazem parte do grupo de pesquisa Perio-Implante UFPE, em especial, a doutoranda Sinara Cunha, por se mostrar disponível e solícita todas as vezes que a recorri para tirar dúvidas.

À professora Renata Almeida, por ter sido peça-chave na construção desse trabalho e por me fazer acreditar que era possível sua realização.

À Marcela Côrte Real, por todos os momentos de aprendizado compartilhados durante esses dois anos, de uma forma leve e tão divertida.

À Lavínia Potter, por ter se tornado uma grande amiga durante essa caminhada. Obrigada por deixar tudo mais leve e ter sempre palavras de apoio e carinho nos momentos de aflição. Sou grata por nossos caminhos terem se cruzado e por termos trilhado juntas até o final. “Lavínia, eu não sei o que seria de mim sem você, obrigada!”

À Ruana Brandão, por estar comigo desde o início dessa jornada. Seu incentivo para minha inscrição no mestrado foi fundamental para que hoje isso tudo fosse possível. Muito obrigada por tudo, tenho muita sorte em ter sua amizade desde a graduação, e por dividir os momentos de felicidade, conquistas e dificuldades. Que sigamos assim, sempre juntas.

A todos os meus amigos e familiares, por me apoiarem e por muitas vezes serem a pausa necessária no meio do caminho, para que eu pudesse prosseguir com o desenvolvimento desse trabalho. Obrigada por sempre acreditarem em mim.

Aos professores membros da Pré-Banca e Banca, por aceitarem o convite e por todas as contribuições dadas ao trabalho.

À Universidade Federal de Pernambuco, UFPE, pela oportunidade de cursar um Programa de Pós-graduação de qualidade e a todos os professores que fazem parte do corpo docente da Graduação e da Pós-graduação em Odontologia. Agradeço por todos os ensinamentos adquiridos.

Minha gratidão a todos que contribuíram de forma direta ou indireta para o desenvolvimento desse trabalho.

Muito obrigada!

RESUMO

A definição do tempo ideal de fotopolimerização de cimentos resinosos duais e fotoativados para atingirem uma Taxa de Conversão (TC) mais adequada ainda é um desafio clínico. O objetivo dessa revisão foi verificar a influência do tempo de fotopolimerização na taxa de conversão dos cimentos resinosos duais e fotoativados. Foi realizada uma busca nas bases de dados Medline/Pubmed, Embase, Scopus, Web of Science e BVS, complementada por busca na literatura cinzenta e busca manual de artigos publicados até outubro de 2021. Foram selecionados estudos in vitro, contendo ≥10 amostras, que apresentavam a taxa de conversão de cimentos resinosos duais ou fotoativados, fotopolimerizados por diferentes tempos, através de discos de cerâmicas. As etapas de elegibilidade, extração de dados e avaliação de qualidade dos estudos e risco de viés foram realizadas de forma independente e duplicada. De 3.592 citações recuperadas, 15 artigos preencheram os critérios de elegibilidade e seguiram para extração de dados. Dentre os 15 estudos incluídos na revisão, houve uma variação de 3 a 120 segundos do tempo de fotopolimerização dos cimentos resinosos e apenas um estudo apresentou TC menor ao utilizar um tempo de fotopolimerização maior que 20s, com diferença estatisticamente significativa. O tipo de cerâmica mais utilizada foi a de dissilicato de lítio, observada em 9 estudos e os cimentos fotopolimerizados através desse material, apresentaram as taxas de conversão mais elevadas. Além disso, os cimentos resinosos duais apresentaram taxas de conversão mais elevadas em comparação aos fotoativados, para todos os tempos de fotopolimerização testados com ambos os tipos. Com a heterogeneidade dos estudos e por apresentarem em sua maioria um risco médio de viés, a força de evidência torna-se limitada. Concluiu-se, portanto, que, o tempo de fotopolimerização parece influenciar na taxa de conversão dos cimentos resinosos, e que um tempo maior que 20 segundos proporciona, em geral, maiores taxas de conversão, n+o entanto, não há uma padronização na literatura de qual seria o tempo ideal para obtenção da melhor taxa de conversão dos cimentos resinosos.

Palavras-chave: cimentos dentários; polimerização; espectroscopia FTIR

ABSTRACT

The definition of the ideal time of light polymerization influence of dual and photoactivated resin cements to achieve more adequate degree of conversion (DC) is still a clinical challenge. The purpose of this review was to verify the influence of light polymerization time on the DC of dual and photoactivated resin cements. A Medline/Pubmed, Embase, Scopus, Web of Science and VHL databases search was performed, complemented by search in the grey literature and manual search for articles published from 1966 until December 2021. In vitro studies containing ≥10 specimen were selected, which presented the DC of dual or photoactivated resin cements, photoactivated for different times, through ceramic discs. Eligibility steps, data studies and assessment of study quality and risk of bias were independently performed and in duplicate. Of the 3,592 citations recovered, 13 articles met the inclusion criteria and followed for data extraction. Among studies included, variation of 3 to 120 seconds(s) in the light polymerization of resin cements was observed and only one study showed lower DC, through light polymerization for 20s, with statistically significant difference. The type of ceramic most used was lithium disilicate, observed in 8 studies and the resin cements light polymerized through this material showed the highest DC. In addition, dual resin cements showed higher DC compared to photoactivated, for all light polymerization times tested with both types. Due to the heterogeneity of studies and the fact that most of them present average risk of bias, the strength of evidence becomes limited. It was concluded, therefore, that the light polymerization time seems to influence the DC of resin cements, and that a time greater than 20s provides, in general, higher DC, however, there is no standardization in literature of what would be the ideal time to obtain the best DC of resin cements.

Keywords: dental cements; polymerization; spectroscopy

LISTA DE ILUSTRAÇÕES

DISSERTAÇÃO

ARTIGO - DOES THE LIGHT POLYMERIZATION TIME INFLUENCE THE DEGREE OF CONVERSION OF RESIN CEMENTS? A SYSTEMATIC REVIEW OF IN VITRO STUDIES

LISTA DE TABELAS

LISTA DE ABREVIATURAS, SIGLAS E SÍMBOLOS

ATR	Reflectância total atenuada
B.C.F.V.	Bruna de Carvalho Farias Vajgel
BVS	Biblioteca Virtual em Saúde
°C	Graus Centígrados
CAD/CAM	*Computer-aided design/Computer-aided manufacturing*
cm^{-1}	Centímetros elevado à potência de menos 1
CQ	Canforoquinona
DC	*Degree of conversion*
DOI	*Digital Object Identifier*
FTIR	Espectroscopia no Infravermelho com Transformada de Fourier
GC	Grau de conversão
H	Hora(s)
HT	Alta translucidez
HO	Alta opacidade
LED	*Light Emitting Diode* (Diodo emissor de luz)
L.P.M.A.	Lavínia Potter Miranda Alencar
LT	Baixa translucidez
MeSH	*Medical subject headings*
M.H.M.	Maria Heloísa Martins
Min	Minuto(s)
Mm	Milímetros
MT	Média translucidez
mW/cm^2	Miliwatt(s) por centímetro(s) quadrado
N, N° e n	Número
Nm	Nanômetro(s)
NR	Não reportado
PAC	*Plasma arc curing*
PICOS	População/intervenção/comparação/*outcomes/study type*

PRISMA-P	*Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols*
PT	Pulso Tardio
QTH	Quartzo-Tungstênio-Halogênio
S	Segundo(s)
SS	*Soft-start*
T	Translúcida
TC	Taxa de conversão
UFPE	Universidade Federal de Pernambuco
µm	Miicrometro(s)

SUMÁRIO

1 INTRODUÇÃO

Os cimentos resinosos são os materiais mais utilizados para cimentação das restaurações indiretas de cerâmicas. Em geral, são compostos por uma matriz polimérica à base de monômeros de dimetacrilato, partículas de carga e pigmentos,[1, 2] podendo ser classificados de acordo com seus modos de ativação, como quimicamente ativados, fotoativados ou ativados pela combinação de ambos (duais).[2, 3]

O protocolo de fotopolimerização tem um efeito significativo na taxa de conversão (TC),[4, 5] que representa a porcentagem de ligações duplas de carbono polimerizadas[6], a partir da razão entre as ligações duplas de carbono alifáticas restantes em uma amostra polimerizada para o número total de ligações duplas de carbono na amostra não polimerizada. Para obtenção de restaurações cerâmicas com prognóstico favorável, uma alta TC do cimento resinoso deve ser alcançada.[4, 7] A literatura relata que uma TC clinicamente aceitável deve estar entre 60 e 75 %,[2] no entanto, esses valores ainda são poucos discutidos quanto as suas repercussões na prática clínica.

Está bem estabelecido que, quando os cimentos resinosos atingem uma adequada TC, há uma redução da microinfiltração, da quantidade de monômeros residuais e, assim, uma diminuição potencial de irritação pulpar e sensibilidade pós-operatória.[1, 2] Além disso, aumenta as propriedades físicas, a estabilidade da cor e a resistência de união entre o substrato dental e o cimento resinoso.[3]

Muitos fatores afetam a TC e devem ser levados em consideração, como o tipo de cerâmica, sua espessura, tonalidade e translucidez, a composição do cimento resinoso, intensidade, modo de ativação, distância do dispositivo de fotopolimerização usado e o tempo de fotopolimerização.[4, 5, 8] O tempo de exposição e a porcentagem de luz transmitida através da cerâmica afetarão a quantidade de energia entregue, influenciando a TC dos monômeros e microdureza do cimento.[9]

Quando o cimento resinoso não atinge uma alta conversão monomérica, poderá resultar em maiores valores de sorção e de solubilidade de água, causando uma degradação mais rápida.[2] Além disso, alteram a estabilidade dimensional e diminuem a união dos cimentos resinosos às estruturas dentais, prejudicando a longevidade clínica das restaurações.[2, 8, 10]

Clinicamente, devido a otimização do tempo de trabalho, há uma preferência pela utilização de tempos de fotopolimerização mais curtos. Portanto, os fabricantes tem se esforçado continuamente para aumentar a irradiância das unidades fotopolimerizadoras.[11, 12]

Baseado nisso, a maioria das unidades fotopolimerizadoras utilizam a tecnologia diodo emissor de luz (LED) com um único diodo de alta potência. Estes dispositivos de alta potência foram estudados como uma solução para aumentar a TC dos cimentos resinosos usados em restaurações de cerâmica.[12] Dentre eles, a unidade fotopolimerizadora LED Bluephase G2, fabricada pela Ivoclar Vivadent, a qual afirma que o dispositivo precisa ser usado por apenas 10 segundos(s) no modo de alta potência para fotopolimerizar o cimento resinoso através de cada milímetro de cerâmica.[1]

Vários fabricantes recomendam diferentes tempos de fotopolimerização. Dentre eles, tempos de fotopolimerização de 20s ou menos, para alguns materiais recentes, dependendo da radiação fornecida pelo fotopolimerizador.[9, 13] Martins et al[12] estabeleceram que os tempos de fotopolimerização abaixo de 20s requerem potências entre 3200 e 3500 mW/cm2 para uma TC aceitável.[12]

No entanto, a maioria dos fabricantes não consideram a espessura da cerâmica ao recomendar protocolos de fotopolimerização para cimentos de resina de cura dupla, que é um dos principais fatores que determina a quantidade de transmissão de luz.[13] Não há na literatura revisões sistemáticas que analisem a influência do tempo de fotopolimerização de diferentes tipos de fotopolimerizadores na TC dos cimentos resinosos.

Baseado nisso, o objetivo principal do presente estudo foi verificar a influência do tempo de fotopolimerização na TC dos cimentos resinosos duais e fotoativados, através de uma revisão sistemática.

2 OBJETIVOS

2.1 Geral

O objetivo do presente estudo foi verificar a influência do tempo de fotopolimerização na TC dos cimentos resinosos duais e fotoativados, através de uma revisão sistemática.

2.2 Específicos

- Estabelecer se há diferença na TC dos cimentos resinosos fotoativados por 20s em comparação aos diferentes tempos de fotopolimerização;
- Avaliar se há diferença na TC dos cimentos resinosos de acordo com os tipos de cerâmicas sobrepostas aos cimentos, durante os diferentes tempos de fotoativação;
- Determinar se há diferença na TC dos cimentos resinosos duais comparados aos fotoativados, utilizando diferentes tempos de fotopolimerização.

3 HIPÓTESES

H0: a) Os diferentes tempos de fotopolimerização não influenciam na TC dos cimentos resinosos duais e fotoativados; b) Os tipos de cerâmicas sobrepostas aos cimentos fotopolimerizados não influenciam na TC dos cimentos resinosos duais e fotoativados, durante os diferentes tempos de fotoativação.

H1: a) Os diferentes tempos de fotopolimerização influenciam na TC dos cimentos resinosos duais e fotoativados; b) Os tipos de cerâmicas sobrepostas aos cimentos fotopolimerizados influenciam na TC dos cimentos resinosos duais e fotoativados, durante os diferentes tempos de fotoativação.

H2: a) Há diferença na TC dos cimentos resinosos duais comparados aos fotoativados, utilizando diferentes tempos de fotopolimerização. b) Não há diferença na TC dos cimentos resinosos duais comparados aos fotoativados, utilizando diferentes tempos de fotopolimerização.

4 MATERIAIS E MÉTODOS

4.1 Protocolo de registro

Esta revisão sistemática foi elaborada com base nas diretrizes dos Principais Itens para Realizar Revisões Sistemáticas e Meta-análises (PRISMA-P)[14], e registrada na plataforma *Open Science Framework* (OSF) sob o DOI de registro 10.17605/OSF.IO/KSMQY.

4.2 Questão principal

A pergunta norteadora desta revisão foi baseada na estratégia PICOS (*Population, Intervention, Control, Outcome* e *Study type*), sendo ela "O tempo de fotopolimerização influencia na Taxa de Conversão dos cimentos resinosos duais e fotoativados?". Dessa forma, a população, intervenção, comparação, desfecho e os tipos de estudos foram dispostos como no quadro abaixo.

Quadro 01. Estratégia PICOS

P	**POPULAÇÃO**	Corpos de prova compostos por cerâmicas e cimentos resinosos duais ou fotoativados
I	**INTERVENÇÃO**	Diferentes tempos de fotopolimerização com unidades fotopolimerizadoras LED
C	**COMPARAÇÃO**	Tempo de fotopolimerização de 20s com unidade fotopolimerizadoras LED
O	**DESFECHO**	Avaliação da TC
S	**TIPOS DE ESTUDO**	Estudos *in vitro*

Fonte: A autora (2022)

4.3 Critérios para elegibilidade dos estudos

4.3.1 Tipos de estudos

Estudos *in vitro* relatando o efeito do uso de diferentes tempos de fotopolimerização na TC dos cimentos resinosos, contendo um N maior ou igual a 10. Foram excluídos estudos em animais, estudos *in vivo*, revisões de literatura, relatos de caso, cartas e comentários. Não houve limitação de idioma e do tempo de publicação.

4.3.2 Tipos de população

Corpos de prova de cimentos resinosos fotoativados ou duais obtidos da fotopolimerização através de discos de diferentes tipos de cerâmica.

4.3.3 Tipos de intervenção e comparação

Estudos com pelo menos dois grupos de comparação com diferentes tempos de fotopolimerização dos cimentos resinosos (intervenção), sendo um deles utilizando um tempo de fotopolimerização de 20s (padrão ouro de comparação).

4.4 Resultados avaliados

Foram considerados como resultados a TC (%) dos cimentos resinosos.

4.5 Estratégia de busca

A estratégia de busca foi realizada em bases de dados eletrônicas até outubro de 2021, e complementada pela busca na literatura cinzenta além da busca manual. As bases de dados pesquisadas foram Medline/Pubmed, Embase, Scopus, Web Of Science e BVS. Foram utilizados descritores controlados MeSH Terms ou Emtree Terms para as bases de dados correspondentes, associados aos Keywords, visando aumentar a sensibilidade da busca. As buscas nas demais bases de dados foram adaptadas a partir das buscas utilizadas na Medline/Pubmed e Embase.

A busca na literatura cinzenta foi realizada pelo acesso à plataforma Open Grey, Google Scholar e pela Biblioteca Digital Brasileira de Teses e Dissertações. A busca manual foi realizada a partir da leitura das referências dos estudos incluídos na Revisão Sistemática, além da leitura dos seguintes periódicos especializados na área de interesse da pesquisa: Operative Dentistry, Dental Materials e Journal of Prosthetic Dentistry, nos seis meses anteriores ao momento da seleção dos estudos. Informações ambíguas ou incompletas foram esclarecidas, sempre que possível, pelos autores originais. As estratégias de busca eletrônica utilizadas estão descritas na Tabela 1.

Esses termos foram combinados da seguinte maneira: MeSH Terms/ Emtree OR Keywords, associados com o operador booleano AND para os termos de População, Intervenção e Desfecho (População AND Intervenção AND Desfecho).

Tabela 1. Estratégia de busca utilizada para cada base de dados.

Base de dados	**Estratégia de busca utilizada**
PubMed/MEDLINE	(((((("Time Factors"[Mesh]) OR ("Materials Testing"[Mesh])) OR ("Time Factor*"[Title/Abstract])) OR ("Material Testing"[Title/Abstract])) OR ("degree of conversion"[Title/Abstract])) OR ("conversion

	degree"[Title/Abstract])) AND (((((((((("Curing Lights, Dental"[Mesh]) OR (Polymerization[Mesh])) OR ("Light-Curing of Dental Adhesives"[Mesh])) OR ("Curing Light, Dental"[Title/Abstract])) OR (Polymerization[Title/Abstract])) OR ("Light-Curing of Dental Adhesives"[Title/Abstract]))) OR ("dental curing light"[Title/Abstract])) OR ("dental light-curing"[Title/Abstract])) OR (photoactivation[Title/Abstract])) OR (photopolymerization[Title/Abstract])) AND ((("Resin Cements"[Mesh]) OR ("Resin Cement*"[Title/Abstract])) OR ("Cement, Resin"[Title/Abstract]))
Embase	('resin cement'/exp OR 'resin cement' OR 'resin cement*' OR 'cement, resin') AND ('polymerization' OR 'photoactivation' OR 'curing light, dental' OR 'polymerization'/exp OR polymerization OR 'light-curing of dental adhesives'/exp OR 'light-curing of dental adhesives' OR 'dental curing light'/exp OR 'dental curing light' OR 'dental light-curing'/exp OR 'dental light-curing' OR 'photoactivation'/exp OR photoactivation OR photopolymerization) AND ('time factor'/exp OR 'time factor' OR 'materials testing'/exp OR 'materials testing' OR 'degree of conversion'/exp OR 'degree of conversion' OR 'conversion degree')
Scopus	TITLE-ABS-KEY(("Resin Cement*" OR "Cement, Resin") AND ("Curing Light, Dental" OR Polymerization OR "Light-Curing of Dental Adhesives" OR "dental curing light" OR "dental light-curing" OR photoactivation OR photopolymerization) AND ("Time Factor*" OR "Material Testing" OR "degree of conversion" OR "conversion degree"))
Web of Science	TS=("Resin Cement*" OR "Cement, Resin") AND TS=("Curing Light, Dental" OR polymerization OR "Light-Curing of Dental Adhesives" OR "dental curing light" OR "dental light-curing" OR photoactivation) AND TS=("Time Factor*" OR "Material Testing" OR "degree of conversion" OR "conversion degree")
Virtual Health Library	(mh:("resin cements")) OR ("resin cement*") OR ("cement, resin") AND (mh:("curing lights, dental")) OR (mh:(polymerization)) OR (mh:("light-curing of

	dental adhesives”)) OR (“curing light, dental”) OR (polymerization) OR (“light-curing of dental adhesives”) OR ("dental curing light ") OR ("dental light curing") OR ("photoactivation") OR ("photopolymerization") AND (mh:(“time factors”)) OR (mh:(“materials testing”)) OR (“time factor*”) OR (“material testing”) OR (“degree of conversion”) OR (“conversion degree”)

Fonte: A autora (2022)

Esses termos foram combinados da seguinte maneira: *MeSH Terms/Emtree OR Keywords*, associados com o operador booleano *AND* para os termos de População, Intervenção e Desfecho (População *AND* Intervenção *AND* Desfecho).

4.6 Avaliação de elegibilidade dos estudos

A seleção dos estudos foi realizada em duas etapas por dois avaliadores (M.H.M e L.P.M.A.), com os resultados avaliados de maneira independente: 1) leitura dos títulos e resumos e 2) leitura de texto completo. Qualquer desacordo entre os avaliadores foi resolvido através de consenso, e na não obtenção de um consenso, um terceiro revisor (B.C.F.V.) foi consultado. O valor de Kappa foi calculado para determinar a concordância entre os pesquisadores durante as etapas de seleção dos estudos.

A primeira fase da pesquisa, a análise dos títulos e resumos, foi realizada para eliminar os títulos e resumos que não preenchiam os critérios de elegibilidade estabelecidos no protocolo de pesquisa. A segunda etapa, a análise dos textos completos foi realizada de acordo com os critérios de inclusão e exclusão previamente estabelecidos, considerando as características dos tipos de estudo, da população, intervenção e resultados.

4.7 Métodos de extração de dados

Um formulário de extração de dados (Apêndice A), projetado especificamente para a pesquisa, foi utilizado para registrar todas as informações importantes com detalhes dos estudos selecionados. O preenchimento do formulário foi executado pelos dois avaliadores (M.H.M e L.P.M.A.) de forma independente. Os dados coletados dos estudos foram baseados nas questões importantes para a pesquisa, tais como: a) características da população (n° total de amostras; n° de amostrras por grupo experimental; tipo(s) de cerâmica(s); marca(s) e fabricante(s) da(s) cerâmica(s); espessura(s) da(s) cerâmica(s); tonalidade da(s) cerâmica(s); lote(s) da(s) cerâmica(s); tipo(s) de cimento(s) resinoso(s); marca(s) e fabricante(s) do(s) cimento(s) resinoso(s); espessura(s) do(s) cimento(s) resinoso(s); tonalidade(s) do(s) cimento(s) resinoso(s); lote(s) do(s) cimento(s) resinoso(s); b) da intervenção: marca(s) e fabricante(s) do(s) fotopolimerizador(es); irradiância(s) do(s) fotopolimerizador(es); modo(s) utilizado(s) para fotopolimerização; tempo(s) de fotopolimerização; protocolo de fotopolimerização utilizado; c) dos resultados: intervalo(s) de tempo(s) entre a fotopolimerização e avaliação da TC; instrumento para avaliação da TC; método(s) utilizado(s) para mensuração da TC; marca(s) e fabricante(s) do aparelho utilizado para mensurar a TC; resolução(es) do(s) aparelho(s); n° de varreduras por espectro; picos de absorbância; e d) do tipo de estudo: estudo(s) in vitro, país do estudo e financiamento.

4.8 Avaliação do risco de vieses e qualidade

O risco de viés e qualidade dos estudos incluídos foram avaliados de forma independente por dois revisores (M.H.M e L.P.M.A.), adaptado com base em parâmetros utilizados anteriormente em revisões sistemáticas de estudos in vitro de Martins et al[12, 15] e Miotti et al.[12, 15]

Para a análise de qualidade dos estudos, foram utilizados os seguintes parâmetros: (A) divisão dos espécimes em grupos de forma aleatória; (B) padronização do preparo dos corpos-de-prova; (C) descrição da metodologia de manipulação do cimento resinoso; (D) utilização de todos os materiais de acordo com as instruções do fabricante; (E) implementação do protocolo de operador único; (F) demonstração do cálculo do tamanho da amostra; (G) cegamento do operador da máquina de teste; e (H) o desenho do teste e o cálculo do grau de conversão.[12]

A avaliação do risco de viés foi estabelecida por uma pontuação recebida por cada parâmetro encontrado na descrição do artigo: 1, se o parâmetro foi corretamente descrito no texto; 0, se a informação não foi descrita no texto. A partir disso, será calculado de acordo com a soma dos parâmetros observados nos estudos: 0-2 = alto risco, 3-5 = risco médio e 6-7 = risco baixo de viés.[15]

4.9 Síntese e análise de dados

Os dados coletados foram agrupados em tabelas de evidência. Uma análise descritiva foi realizada para comparar os dados obtidos de acordo com as características das populações, das intervenções e dos resultados dos estudos incluídos.

5 RESULTADOS

5.1 Artigo - Does the light polymerization time influence the degree of conversion of resin cements? A systematic review of in vitro studies

CLINICAL IMPLICATIONS

Several recommendations on the polymerization time of resin cements through ceramics are given by manufacturers and in literature, leaving dentists unsure about the best time to achieve adequate DC. The present review will contribute to a critical analysis of the influence of different polymerization times of resin cements, providing a better clinical decision about the polymerization time.

INTRODUCTION

Resin cements are the most used materials for cementing indirect ceramic restorations. In general, they are composed of a polymeric matrix based on dimethacrylate monomers, filler particles and pigments,[1, 2] and can be classified according to their activation modes, as chemically activated, photoactivated or activated by the combination of both (dual).[2, 3]

The light polymerization protocol has significant effect on DC,[4, 5] which represents the percentage of polymerized carbon double bonds,[6] from the ratio of aliphatic carbon double bonds remaining in a polymerized sample to the total number of carbon double bonds in the unpolymerized sample. To obtain ceramic restorations with favorable prognosis, high DC of the resin cement must be achieved.[4, 7] The literature reports that clinically acceptable DC must present between 60 and 75 %; however, these values are still rarely discussed in terms of their impact on clinical practice.[2]

It is well established that when resin cements reach adequate DC, there is reduction in microleakage, in the amount of residual monomers and, thus, a potential decrease in pulpal irritation and postoperative sensitivity.[1, 2] In addition, it increases the properties physical properties, color stability and bond strength between the dental substrate and the resin cement.[3]

Several factors affect DC and must be taken into consideration, such as type of ceramic, its thickness, tonality and translucency, the composition of the resin cement, intensity, mode of activation, distance from the light-polymerization unit (LPU) used and the light polymerization time.[4, 5, 8] The exposure time and the percentage of light transmitted through the ceramic will affect the amount of energy delivered, influencing the DC of the two monomers and the cement microhardness .[9]

When resin cement does not achieve high monomeric conversion, it may result in higher sorption and water solubility values, causing faster degradation.[2] In addition, there is a change in dimensional stability and a decrease in the bond between resin cements and dental structures, impairing the clinical longevity of restorations.[2, 8, 10]

Clinically, due to the optimization of the working time, there is a preference for the use of shorter light polymerization times. Therefore, manufacturers have continually strived to increase the irradiance of LPUs.[11, 12]

Based on the above, most LPUs use light-emitting diode (LED) technology with a single high-power diode. These high power devices have been studied as a solution to increase the DC of cements used in ceramic restorations.[12] Among them, Bluephase G2 LED LPU (Ivoclar Vivadent), which must be used for only 10s in high power mode to light polymerize the resin cement through each millimeter of ceramic.[1]

Various manufacturers recommend different light polymerization times, of 20s or less, for some recent materials, depending on the radiation provided by LPU.[9, 13] Martins et al[12] established that polymerization times below 20s require powers between 3200 and 3500 mW/cm^2 for acceptable DC.[12]

However, most manufacturers do not consider the ceramic thickness when recommending light polymerization protocols for dual-light resin cements, which is one of the main factors that determines the amount of light transmission.[13] There are no systematic reviews in literature that analyze the influence of the light polymerization time of different types of LED LPUs on the DC of resin cements.

In this context, the main purpose of this systematic review was to verify the influence of light polymerization time on the DC of dual and light-polymerized resin cements.

MATERIALS AND METHODS

This systematic review was performed according to the Preferred Reporting Items for Systematic review and Meta-Analysis Protocols (PRISMA-P),[14] and was registered in the Open Science Framework (OSF) platform under registration DOI 10.17605/OSF.IO/KSMQY.

Research Question

The research question of this review was based on the PICOS approach (Population, Intervention, Control, Outcome and Study Type), which is "Does the light polymerization time influence the DC of dual and light-polymerized resin cements?". Thus, the Population (P) was composed of specimens composed of ceramics and dual or light-polymerized resin cements, the Intervention (I) was the different light polymerization times with LED LPUs, the Comparison (C) was the light polymerization time of 20s with LED LPUs, the Outcome (O) was the DC assessment and the Study types (S) were in vitro studies included.

Criteria for the eligibility of studies

In vitro studies were included reporting the effect of the use of different light polymerization times on the DC of resin cements containing $N \geq 10$; studies containing specimens of light-polymerized or dual resin cements obtained from light-polymerization through discs of different types of ceramics and studies with at least two comparison groups that used LED LPUs with different times for the light-polymerization of resin cements (intervention), one of them using light polymerization of 20s (gold standard). Animal studies, in vivo studies, literature reviews, case reports, letters, comments and unpublished studies were excluded. There was no language or publication time limitation.

Search strategy

The search strategy (Table 1) was carried out in electronic databases to retrieve studies published from 1966 until December 2021, and complemented by the search in the gray literature in addition to the manual search. Databases searched were Medline/Pubmed, Embase, Scopus, Web Of Science and VHL. Controlled descriptors MeSH Terms or Emtree Terms were used for the corresponding databases, associated with Keywords, in order to increase the search sensitivity. Searches in the other databases were adapted from searches used in Medline/Pubmed and Embase. These terms were combined as follows: MeSH Terms/Emtree OR Keywords, associated with the AND Boolean operator for the Population, Intervention, and Outcome terms (Population AND Intervention AND Outcome).

The search in the gray literature was carried out by accessing the Open Gray platform, Google Scholar and the Brazilian Digital Library of Theses and Dissertations. The manual search was performed by reading the references of studies included in the Systematic Review, in addition to reading the following specialized journals in the area of interest: Operative Dentistry, Dental Materials and Journal of Prosthetic Dentistry, in the six months prior to the moment of the selection of studies. Ambiguous or incomplete information was clarified, whenever possible, by the original authors.

Eligibility assessment of studies

The selection of studies was carried out in two stages independently by two evaluators (M.H.M and L.P.M.A.): 1) reading titles and abstracts and 2) reading the full text. Any disagreement between evaluators was resolved through consensus, and in the absence of consensus, a third reviewer (B.C.F.V.) was consulted. The level of agreement between reviewers was calculated using Kappa statistics for the first and second screening stages.

Data extraction methods

A data extraction form specifically designed for the research was used to record all important information with details of selected studies and was independently completed by the two evaluators (M.H.M and L.P.M.A.).

Data collected from studies were based on important questions for the research, such as: a) characteristics of the population (total number of specimens; number of specimens per experimental group; types, brands, manufacturers, batches, thickness and shade of the ceramics and of resin cements; b) intervention: brands, manufacturers, irradiance, mode used for light polymerization of LPUs; light polymerization times and protocol used; c) results: time interval between light polymerization and DC evaluation; instrument and methods for the assessment of DC; brands and manufacturers of the device used to measure DC; resolutions of devices; number of scans per spectrum and absorbance peaks.

Assessment of risk of bias and quality

The risk of bias and quality of included studies were independently assessed by two reviewers (M.H.M and L.P.M.A.), adapted based on parameters previously used in systematic reviews of in vitro studies by Martins et al[12] and Miotti et al.[15] For the analysis of the quality of studies, the following parameters were used: (A) Random division of specimens into groups; (B) standardization of specimen preparation; (C) description of the resin cement manipulation methodology ; (D) use of all materials according to the manufacturer's instructions; (E) implementation of the single operator protocol; (F) demonstration of the specimen size calculation ; (G) blinding of the testing machine operator; and (H) test design and DC calculation.[12] The risk of bias was assessed by a score received for each parameter found in the article description: 1, if the parameter was correctly described in the text; 0, if the information was not described in the text. From this, it will be calculated according to the sum of parameters observed in studies: 0-2 = high risk, 3-5 = medium risk and 6-7 = low risk of bias.[15]

Collected data were grouped into evidence tables. A descriptive analysis was performed to compare data obtained according to the characteristics of populations, interventions and results of included studies.

RESULTS

Selection of studies

The search in databases resulted in 3.592 potentially eligible references, 1.175 from Pubmed/Medline, 985 from Embase, 1.187 from Scopus, 108 from Web of Science and 136 from the Virtual Health Library (VHL). After removing duplicates, the title and abstract screening step was performed, and 32 articles were selected for full text analysis. After reading these articles, 13 studies met all eligibility criteria and were included in the final review. Table 2 shows excluded publications and reasons for exclusion.

The kappa value for inter-reviewer agreement was 0.85 at title and abstract screening and 0.90 at full-text reading, representing excellent agreement between reviewers.[16]

Characteristics of studies

According to the exclusion and inclusion criteria, all articles selected for review were in vitro studies and had total number of specimens ≥ 10, ranging from 18[17] to 200[18] specimens. The number of specimens per experimental group ranged from 03[17, 19] to 20,[5] where most studies had 5 specimens per experimental group.[11, 13, 18, 20, 21] As for the different light polymerization times tested, variation from 3[17] to 120s was observed.[13, 22] Most studies[5, 13, 17-20, 22-25] compared two different light polymerization times, including 20s. Only 3 studies[1, 21, 26] compared more than two different light polymerization times, ranging from 20 to 60s.

Characteristics of the population

The characteristics of the population of studies included in this review are summarized in Table 3. The types of ceramics used to light polymerization the overlying dual and light-polymerized resin cements were: lithium disilicate ceramics,[1, 13, 17, 20, 21, 23, 25, 26] monolithic zircônia,[18, 22, 25] feldspathic ceramics,[5, 19] hybrid ceramics[5, 24] and nanoceramic.[5]

Types of ceramics

Among included studies, the most used type of ceramic was lithium disilicate, used in at least one of the experimental groups of 8 studies,[1, 13, 17, 20, 21, 23, 25, 26] with thickness of 1 .5mm[20, 23] and shade A2[1, 20, 23, 25] the most used. Another type of ceramic was monolithic zirconia, used in at least one of the experimental groups,[18, 22, 25] with thicknesses ranging from 0.5[18] to 2mm,[18] and shades also differ from each other, being A1-D4,[22] A2 -T and A2-HT.[25]

As for the feldspathic ceramic,[5, 19] thickness variation from 1[5] to 2mm[19] was observed and the shades of ceramics were also different from each other, being A2,[5] 0M1, 2M2 and 5M3.[19] Hybrid ceramics[5, 24] were used, with thickness variation from 0.5[24] to 2mm[24], and both studies used the 2M2 color.[5, 24] Another type of material used was nanoceramic[5] with thickness of 1mm and shade A2.[5]

Types of resin cements

Regarding the types of resin cements present in included studies, most used only dual resin cements,[13, 18-20, 22, 23, 25, 26] but only light-polymerized resin cements[1, 5, 17, 21] or both were used.[24] As for the thickness of the dual resin cement layer, variation from 40µm[18, 25] to 1mm was observed.[26] Regarding shade, 6 studies[13, 18, 20, 22, 23, 25] did not report this information and 2 of them mentioned only the cement translucency .[13, 18]

Among studies[1, 5, 17, 21] that used only light-polymerized resin cement, 2[5, 17] used the same resin cement brand RelyX Veneer (3M ESPE) with the same thickness (0.1mm) and translucency (translucent); however, shade was not reported. Finally, only the study by Barutcigil et al[24] used dual and light-polymerized resin cements. Information regarding the different commercial brands of resin cements and manufacturing batches is presented in Table 3.

Intervention characteristics

Among studies, 4[13, 18, 20, 23] did not mention the LPU mode during light polymerization. As for irradiance, variation from 25.6 (0.9)[13] to 2418.0 (40.7)mW/cm²[17] was observed among studies, and only one study[1] did not report it. The most used LPU brands were Valo, (Ultradent)[17, 22, 24] and BluePhase G2 (Ivoclar Vivadent).[1, 5, 13] As for the light polymerization time, times of 3s,[17] 40s,[1, 18-20, 23, 26] 60s,[1, 21, 25] 40s[1, 18-20, 23, 26] and 120s were used.[13, 22]

Information on the different brands used in studies, as well as the light polymerization protocol, is described in Table 03.

Characteristics of results

All studies used the spectroscopy method to measure DC (Table 4). Among studies, Fourier Transform Infrared Spectroscopy (FTIR) with Attenuated Total Reflectance (ATR)[1, 18-23] or just FTIR Spectroscopy was the most used method.[5, 13, 17, 24-26] Regarding the time interval between light polymerization and DC measurement, most studies[1, 18, 21-23] evaluated it immediately and/or after 24 hours(h) of light polymerization.

Information regarding the characteristics of devices used for DC evaluation, such as manufacturer, resolution, number of scans and absorbance peak, as well as the statistical significance of DC data presented and statistical tests used, is summarized in Table 4.

Dual resin cements

For specimens composed of dual resin cements light polymerization using lithium disilicate ceramic, DC variation was observed according to the different light polymerization times, as follows: a) 20s: ranging from 48.43 ± 3.11[13] to 82.82 ± 0.94 %;[13] b) 40s: 45.1 ± 2.6[23] to 72.4 ± 1.3 %;[20] c) 60s: 59.62 ± 3.43[25] to 70.87 ± 1.90 %;[25] d) 120s: 63.39 ± 2.96[13] to ± 86.48 %.[13]

The DC variation observed for dual resin cements when light polymerized through Monolithic Zirconia, from different light polymerization times were: a) 20s: ranging from 51.84 ± 2.76[25] to 63.3 ± 2.9 %[22]; b) 40s: 62.54 ± 0.83[18] to 65.58 ± 0.56 %;[18] c) 60s: 58.68 ± 1.57[25] to 69.47 ± 2.16 %;[25] d) 120s: 58.1 ± 5.2[22] to 62.9 ± 1.9 %.[22]

Another type of material used to overlay the dual resin cement was feldspathic ceramic,[19] where DC variation was found for the following photoactivation times: a) 20s: 10.70 ± 1.40 to 42.57 ± 2.63 %; b) 40s: 16.97 ± 2.88 to 49.20 ± 0.8 %.[19] Nanoceramics were not used for overlapping dual resin cements and only one[24] study used hybrid ceramic for 20s of light polymerization and obtained DC variation from 80.66 ± 5.79 to 84.04 ± 1.46 %.[24]

When correlating the DC variation of dual resin cements with the type of LPU used, and the different thicknesses and shades of ceramics superimposed on cements, it was observed that through the lithium disilicate ceramics, the lowest DC was for time of 20s,[13] and the highest for time of 120s,[13] both from light polymerization with Bluephase (Ivoclar Vivadent) LPU; however, through 4mm and 2mm ceramics with A3-LT shade, respectively.[13] When light polymerized from zirconia, the lowest DC occurred using light polymerization time of 20s, while the highest DC, with time of 60s, both using Dr's Light LED unit (Good

Doctors Co) through 1mm A2T ceramic; however, light polymerized from low and high irradiance, respectively.[25]

As for cements superimposed by feldspathic ceramics and nanoceramics, the lowest DC were from photoactivation for 20s and the largest for 40s, using Elipar FreeLight (3M ESPE) LPU through 2mm thick ceramic, but with shades (A3 Yellow -5M3 and T-2M2, respectively).[19]

Light-polymerized resin cements

For resin cement specimens light-polymerized using lithium disilicate ceramics, DC variation of was observed according to the different light polymerization times, as follows: a) 3s: ranging from 39.8 ± 0.6[17] to 61.8 ± 1.1 %;[17] b) 20s: 57.4 ± 0.3[21] to 76.6 ± 1.0 %;[21] c) 40s: 62.4 ± 0.31[21] to 79.9 ± 0.2 %;[21] d) 60s: 63.9 ± 0.71[21] to 80.0 ± 0.4 %.[21]

The DC variation observed for light-polymerized resin cements when polymerized through zirconia was not tested in any of included studies. A study[5] measured DC from the light polymerization of a resin cement light-cured through feldspatic ceramics, where the following variation was found according to different light polymerization times: a) 10s: 51 ± 1.68 to 59 ± 3.13 %; b) 20s: 56 ± 1.29 to 65 ± 2.72 %. In both times, the variation occurred from the light polymerization modes of the LPU, being low and Soft-Start, respectively.[5]

In addition, the light-polymerized resin cement was also evaluated using nanoceramic.[5] DC variations for the different light polymerization times were: a) 10s: 43 ± 1.91 to 49 ± 2.54 %;[5] b) 20s: 46 ± 2.19 to 51 ± 2.13 %.[5] Finally, resin cement light-polymerized through hybrid ceramic[5, 24] was also used, from different light polymerization times, with DC variation from a) 48 ± 1.81 to 53 ± 2.69 %;[5] b) 20s: 50 ± 2.93 to 57 ± 3.28 %[5] and c) 30s: 63.58 ± 5.86 to 85.58 ± 3.13 %.[24]

When analyzing the DC variation of resin cements activated with the type of LPU used, and the different thicknesses and shades of ceramics superimposed on cements, it was observed that through the lithium disilicate ceramic, the lowest DC was for time of 3s light polymerized with Valo (Ultradent) in Xtra Power mode, through 2mm ET1 ceramics[17] and the highest TC for 60s with Valo (Ultradent) through 0.3mm MT-A1 ceramic.[21] Using 1mm A2 feldspathic ceramic, the lowest DC was for 3s of light polymerization and the highest for 20s. For photoactivation through nanoceramics, the highest DC was for 10s and the highest for 20s. Both were light polymerized with Bluephase (Ivoclar Vivadent) LPU, with low and Soft-Start mode, respectively.[5]

As for cements overlaid with hybrid ceramics, the lowest DC was with photoactivation for 10s with Bluephase (Ivoclar Vivadent) LPU through 1mm 2M2 ceramic and the highest DC with 30s through 1mm HT-2M2 ceramic with Valo (Ultradent) LPU.[24]

Results of the risk of bias and quality assessment

The risk of bias (Table 5) was calculated taking into account that each parameter found in the article description received: 1- if the parameter was correctly described in the text; and 0 - if the information was not described in the text. From this, it was possible to observe that all studies had medium risk of bias, as their scores were between 3 and 5, with the exception of the study by Faria-e-Silva et al,[17] which presented high risk of bias, whose score was between 0 and 2.

Finally, due to the great heterogeneity of protocols used and the limitations of these studies, it was not possible to carry out a meta-analysis.

DISCUSSION

The results found in studies included in the present systematic review suggest that the light polymerization time influences the DC of resin cements, in which time greater than 20s provides, in general, higher DT of dual and light-polymerized resin cements. Among the 13 studies included in the review, only the study by Barutcigil et al[24] showed lower DC when using light polymerization time greater than 20s, with a statistically significant difference.[1, 5, 13, 17-21, 25, 26] One of the factors that can justify the results found is based on the fact that the exposure time and the percentage of light transmitted through the ceramic will affect the amount of energy delivered to the resin cement, consequently influencing DC.[9]

Among the methods used to evaluate the DC of resin composites, spectroscopy tests are the most suitable methods for this purpose, as they allow detailed measurements of the non-reactive groups of methacrylates.[27] Among them, FTIR spectroscopy is very effective for data acquisition and offers a straightforward approach to addressing the level of polymerization of dental composites by DC monomers. This method measures vibration frequencies of various bonds in molecules and provides information about functional groups in molecules.[24] Based on the above, all included studies evaluated DC using FTIR spectroscopy.

It is known that the type of ceramic and the thickness that overlaps the resin cement during light polymerization influences DC.[1] Thus, it was observed that among evaluated studies, lithium disilicate ceramic was the most used as an overlay material to resin cements, and that, among studies, cements light polymerized through this material presented the highest DC.[1, 13, 17, 20, 21, 23, 25, 26]

The results observed with lithium disilicate ceramics can be justified by the fact that it stands out due to its mechanical efficiency, precision,[28] durability, ability to adhere to resin cements[29] and for presenting more attractive optical and aesthetic properties due to its composition, mainly in terms of translucency, compared to other types of ceramics such as zirconia, considered a more opaque restorative material.[28] In addition, its manufacturing process involves more convenient production time and lower cost, making this ceramic one of the most used in dentistry.[30]

Ceramic thickness also seems to influence the DC of cements, as demonstrated in the study by Jang et al[13], who used time of 120s to light polymerize dual resin cements Rely-X ARC, Duolink, Rely-X U200 and Maxcem Elite, through 2 and 4mm thick ceramics. The Rely-X ARC dual resin cement group, light polymerized through 2mm thick ceramic showed the highest DC and when exposed to 4mm thickness for 20s, they achieved reduced DC ($p<0.05$). However, when exposed to 4mm ceramic for 120s, it resulted in high DC, with no statistically significant difference compared to 2mm ceramic.[13] This evidences that the ceramic thickness can affect the polymerization of the resin cement due to the effect of the light penetration through the ceramic restoration.[17] In addition, in cases of overlapping ceramics of greater thickness, prolonged light polymerization time may be an option to improve the level of polymerization of resin cements.[13]

Although all studies showed higher DC for light polymerize time greater than 20s, only the study by Barutcigil et al[24] showed higher DC for the dual resin cement RelyX U200 light polymerized for 20s through the translucent(T) hybrid ceramic of 1, 1.5 and 2mm of thickness and high translucency (HT) of 1.5 and 2mm, compared to the group that used the light-polymerization resin cement RelyX Veneer for 30s, with statistically significant difference. These results are in agreement with literature, which states that dual resin cements are preferable because they combine light-activated and chemical polymerization,[22] enabling the chemical polymerization system to achieve complete polymerization in dark locations, due to the ceramic overlying the cement during light polymerization, associated with the light-activation mechanism that allows prolonged working time and rapid initial hardening of the material for restoration stabilization.[31]

LED LPUs are currently the “gold standard” for light polymerization. Norrish type II camphorquinone (CQ) is the most common photoinitiator present in resin cements, with light absorption spectrum ranging from about 425 to 495nm, and therefore compatible with the spectral emission profile of LED LPUs. The search for composite resin materials with lighter colors led manufacturers to develop alternative photoinitiators to overcome this limitation, and among the most common, the new Norrish type I photoinitiator based on germanium, commercially known as Ivocerin, stands out. However, type I photoinitiators have absorption peak located at lower wavelength compared to that emitted by monowave LED LPU, with absorption spectrum ranging from about 390 to 445nm, compared to CQ.[9, 21]

Recently, polywave LED LPUs have been developed and have wider spectral emission (390 to 490nm) compared to monowaves.[9, 21] An example of light-polymerized resin cement that contains this light initiator is Variolink Esthetic LC (Ivoclar Vivadent), used in the study by Ramos et al[21] who tested the cement photoactivation through lithium disilicate ceramics using a single LED LPU peak, the Radii Plus (SDI), or polywave LED LPU, the Valo (Ultradent). The results found in the study are in agreement with literature, where DC was higher using polywave LPU, the Valo (Ultradent), compared to monowave LED LPU ($p<0.05$).[21]

Another type of polywave LED LPU tested was Bluephase G2 (Ivoclar Vivadent), which claims time of only 10s in high power mode per millimeter of ceramic.[1] However, when tested for 20s to light polymerize cement light-polymerized resin using lithium disilicate ceramics, reached low DC ($p<0.05$), being recommended to be used for at least 40s.[1]

It is also important to point out that the light polymerization time is just one of the variables that can influence the DC of dual and light polymerization resin cements. As mentioned in literature, there are other parameters that can also influence it, such as the type of ceramic, thickness, shade and translucency, resin cement composition, intensity, activation mode, distance from the light polymerization device used and LPU irradiance .[5, 32]

Based on the results obtained among studies and on the statistical significance among light polymerization times observed in most studies,[1, 19, 21, 24, 25] time greater than 20s of light polymerization is recommended for ceramics with higher opacity and thickness to ensure proper polymerization. However, it is necessary to complement the results of these studies to evaluate the performance of different materials (types of resin cements, ceramics and LPUs) in the oral cavity, since DC alone cannot be attributed to the performance and clinical success of different types of resin cements.

Thus, given the great heterogeneity of studies evaluated, there is a need for new studies based on similar methodological designs to better assess the effectiveness of different light polymerization times on the DC of dual and light-polymerized resin cements. It is also worth mentioning that the results of this review should be interpreted with caution, due to the lack of methodological standardization among studies, the risks of bias found and the interpretation of results obtained from only in vitro studies.

CONCLUSION

Therefore, it could be suggested that the light polymerization time is one of the factors that can influence the DC of resin cements, in which time greater than 20s provides, in general, higher DC of dual and light-polymerized resin cements.

In addition, dual resin cements, in general, showed higher DC compared to light-polymerized resin cements. Finally, ceramics superimposed on cements also affected DC, with lithium disilicate ceramics being the most favorable for higher DC of resin cements.

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TABLES

Table 1. Search methodology used for each database.

Database	Search Strategy Used
PubMed/MEDLINE	((((((("Time Factors"[Mesh]) OR ("Materials Testing"[Mesh])) OR ("Time Factor*"[Title/Abstract])) OR ("Material Testing"[Title/Abstract])) OR ("degree of conversion"[Title/Abstract])) OR ("conversion degree"[Title/Abstract])) AND (((((((((("Curing Lights, Dental"[Mesh]) OR (Polymerization[Mesh])) OR ("Light-Curing of Dental Adhesives"[Mesh])) OR ("Curing Light, Dental"[Title/Abstract])) OR (Polymerization[Title/Abstract])) OR ("Light-Curing of Dental Adhesives"[Title/Abstract]))) OR ("dental curing light"[Title/Abstract])) OR ("dental light-curing"[Title/Abstract])) OR (photoactivation[Title/Abstract])) OR (photopolymerization[Title/Abstract])) AND ((("Resin Cements"[Mesh]) OR ("Resin Cement*"[Title/Abstract])) OR ("Cement, Resin"[Title/Abstract]))
Embase	('resin cement'/exp OR 'resin cement' OR 'resin cement*' OR 'cement, resin') AND ('polymerization' OR 'photoactivation' OR 'curing light, dental' OR 'polymerization'/exp OR polymerization OR 'light-curing of dental adhesives'/exp OR 'light-curing of dental adhesives' OR 'dental curing light'/exp OR 'dental curing light' OR 'dental light-curing'/exp OR 'dental light-curing' OR 'photoactivation'/exp OR photoactivation OR photopolymerization) AND ('time factor'/exp OR 'time factor' OR 'materials testing'/exp OR 'materials testing' OR 'degree of conversion'/exp OR 'degree of conversion' OR 'conversion degree')
Scopus	TITLE-ABS-KEY(("Resin Cement*" OR "Cement, Resin") AND ("Curing Light, Dental" OR Polymerization OR "Light-Curing of Dental Adhesives" OR "dental curing light” OR “dental light-curing" OR photoactivation OR photopolymerization) AND ("Time Factor*" OR "Material Testing" OR "degree of conversion" OR "conversion degree"))
Web of Science	TS=("Resin Cement*" OR "Cement, Resin") AND TS=("Curing Light, Dental" OR polymerization OR "Light-Curing of Dental Adhesives" OR "dental curing

	light" OR "dental light-curing" OR photoactivation) AND TS=("Time Factor*" OR "Material Testing" OR "degree of conversion" OR "conversion degree")
Virtual Health Library	(mh:("resin cements")) OR ("resin cement*") OR ("cement, resin") AND (mh:("curing lights, dental")) OR (mh:(polymerization)) OR (mh:("light-curing of dental adhesives")) OR ("curing light, dental") OR (polymerization) OR ("light-curing of dental adhesives") OR ("dental curing light ") OR ("dental light curing") OR ("photoactivation") OR ("photopolymerization") AND (mh:("time factors")) OR (mh:("materials testing")) OR ("time factor*") OR ("material testing") OR ("degree of conversion") OR ("conversion degree")

Table 2. Excluded studies and reasons for exclusion

Reasons for exclusion	**Nº of excluded studies**
1. Did not use LED LPU	2[33, 34]
2. Did not use different light polymerization times	5[35-40]
3. Did not use 20s light polymerization time	9[4, 9, 11, 41-46]
4. Did not evaluate DC	5[32, 36, 47-49]
5. Did not use ceramics to overlap cement during light polymerization	1[50, 51]
6. Did not report the number of specimens	1[52]
Article not retrieved	2[53, 54]
Unpublished studies	2[55, 56]

DC: Degree of conversion; LED: Light Emitting Diode; LPU: Light-polymerization unit; n°: number

Table 3. Population and intervention characteristics of included studies

Study	**1. Total number of specimens** **2. Number of specimens per experimental group**	**Ceramic** **1. Type** **2. Brand and manufacturer** **3. Thickness** **4. Shade** **5. Batch**	**Resin cement** **1. Type** **2. Brand and manufacturer** **3. Thickness** **4. Shade** **1. 5. Batch**	**LPU** **1. Brand and manufacturer** **2. Irradiance** **3. Mode used for light polymerization**	**Light polymerization times**	**Light polymerization protocol used**
Alovisi et al, 2018[22]	1. N= 48 2. N=8	1. Monolithic Zirconia 2. Katana UTML (Ultra Translucent Multi Layered, Kuraray Noritake Dental Inc.) 3. 1mm 4. A1-D4 5. NR	1. Duals 2. - Rely-X Ultimate/NR - Panavia AS/NR 3. 0.5mm 4. NR 5. NR	1. Valo (Ultradent) 2. 1400mW/cm² 3. High Power	20s or 120s	Light polymerized through ceramic, in direct contact, for 20s or 120s
Alshaafi et al, 2014[1]	1. N=30 2. N=5	1. Leucite-reinforced glass-ceramic material; Fluorapatite glass ceramic material 2. Leucite-reinforced glass-ceramic	1. Light-polymerized (base component) 2. Variolink II (Ivoclar Vivadent)	1. BluePhase G2 (Ivoclar Vivadent) 2. NR 3. High Power	20s, 40s or 60s	Light polymerized through different types of ceramics, for 20s, 40s or 60s

		material: IPS Empress Esthetic (EST) / NR - Fluorapatite glass ceramic material: IPS e.max ZirPress (ZR)/NR 3. 1mm 4. - IPS Empress Esthetic: ETC1 - IPS e.max ZirPress: LT-A2 5. NR	3. 0.5mm 4. A1 5. NR			
Arrais et al, 2014[23]	1. N=42 2. N=7	1. Lithium dissilicate 2. IPS e.max (Ivoclar Vivadent) 3. 1.5mm 4. A2 5. NR	1. Duals 2. - Rely X U100 (3M ESPE) - Maxcem Elite (MX, Kerr Corp) 3. 100-120µm 4. NR 5. NR	1. Radii Plus (SDI) 2. 1500mW/cm² 3. NR	20s or 40s	Light polymerized through ceramic for 20s (Maxcem Elite) or 40s (Rely X U100)
Barutcigil et al, 2020[24]	1. N=80 2. N=10	1. Hybrid ceramic 2. Vita Enamic (VITA Zahnfabrik)	1. Light-polymerized and dual 2. - Light-polymerized:	1. Valo (Ultradent) 2. 1400mW/cm² 3. High Power	30s or 20s	Light polymerized through ceramic for 30s (RelyX

		3. 0.5; 1; 1.5 and 2mm 4. - HT-2M2 - T-2M2 5. 41470	RelyX Veneer (3M ESPE); - Dual: RelyX U200 (3M ESPE) 3. 100µm 4. - RelyX Veneer: A1 - RelyX U200: A2 5. - RelyX Veneer: N776174; - RelyX U200: 628965			Veneer) or 20s (RelyX U200)
Ebeid et al, 2021[5]	1. N=60 2. N=20	1. Nanoceramic; Hibrid ceramic; Feldspathic ceramic 2. - Nanoceramic: Cerasmart - Hibrid ceramic: Vita Enamic - Feldspatchic ceramic: Vita Mark II 3. 1mm 4. - Cerasmart: A2	1. Light-polymerized 2. RelyX Veneer/NR 3. 0.1mm 4. T 5. NR	2. Bluephase/NR 3. 1000mW/cm² 4. Low intesity, high intensity or SS	10s or 20s	Light polymerized with low, high or SS mode through different types of ceramics for 10s or 20s

		- Vita Enamic: 2M2 - Vita Mark II: A2 5. NR				
Faria-e-silva et al, 2017[17]	1. N=18 2. N=3	1. Lithium disilicate 2. IPS Empress Esthetic (Ivoclar Vivadent AG) 3. 0.5; 1 and 2mm 4. ET1 5. NR	1. Light-polymerized 2. RelyX Veneer/NR 3. 0.1mm 4. T 5. NR	1. - SmartLite Focus Pen Style (Dentsply Sirona) - Valo (Ultradent) 2. - SmartLite Focus: 0.5mm: 809.7 ± 4.5mW/cm² 1mm: 633.0 ± 3.6mW/cm² 2mm: 312.0 ± 5.3mW/cm² - Valo (Standard mode): 0.5mm: 1150.3 ± 9.1mW/cm² 1mm: 850.0 ± 6.8mW/cm² 2mm: 356.3 ± 1.5mW/cm² - Valo (XP mode):	20s or 3s	Light polymerized through ceramic, of different thicknesses, for 20s (SmartLite and Valo, Standard mode) or 3s (Valo, XP mode)

				0.5mm: 2418.0 ± 40.7mW/cm² 1mm: 1583.7 ± 17.5mW/cm² 2mm: 847.3 ± 4.6mW/cm² 3. Standard ou XP mode		
Jang et al, 2017[13]	1. N=60 2. N=5	1. Lithium disilicate 2. IPS e.max CAD/CAM (Ivoclar Vivadent) 3. 2 ± 0.01 and 4 ± 0.01mm 4. A3 (LT) 5. NR	1. Duals and duals self-adhesive 2. - Duals: Rely-X ARC (3M ESPE); Duolink (Bisco) - Duals self-adhesives: Rely-X U200 (3M ESPE); Maxcem Elite (Kerr, Orange) 3. 100 ±10µm 4. - Rely-X ARC, Duolink, Rely-X U200: T - Maxcem Elite: clear 5. NR	1. Bluephase (Ivoclar Vivadent) 2. - 2mm ceramic: 128.2 ± 2.6mW/cm² - 4mm ceramic: 25.6 ± 0.9mW/cm² 3. NR	120s or 20s	Light polymerized through ceramics, of different thicknesses, for 120s or 20s.

Oliveira et al, 2012[20]	1. N=72 2. N=6	1. Lithium disilicate 2. IPS e.max (Ivoclar Vivadent) 3. 1.5 or 3mm 4. A2 5. NR	1. Duals 2. - Calibra (Dentsply Caulk) - Variolink II (Ivoclar Vivadent) 3. 100-120µm 4. - Calibra: medium (regular viscosity) - Variolink II: NR/ (low viscosity) 5. NR	1. Optilux 501 (Demetron Kerr) 2. 600mW/cm² 3. NR	20s or 40s	Light polymerized through polyester strip and ceramic for 20s (Calibra) or 40s (Variolink II)
Ozturk et al, 2005[26]	1. N=50 2. N=10	1. Lithium disilicate 2. IPS Empress 2 (Ivoclar Vivadent) 3. 2mm 4. B3 5. NR	1. Dual 2. Variolink II (Ivoclar Vivadent) 3. 1mm 4. - Base: A4 - Catalyst: A3 5. - Base: E1325 - Catalyst: E16059	1. Elipar FreeLight (3M ESPE) 2. Elipar FreeLight: 380mW/cm² 3. NR	20s or 40s	Light polymerized through ceramic for 20s or 40s
Passos et al, 2013[19]	3. N=48 4. N=3	1. Feldspathic ceramic 2. VITA VM7 (Vita Zanhfabrik) 3. 2mm 4. - Base Dentin: 0M1	1. Dual 2. Variolink II (Ivoclar Vivadent) 3. 100µm 4. Yellow, A3 and T	1. Elipar FreeLight 2 (3M ESPE) 2. 900mW/cm² 3. High Power	20s or 40s	Light polymerized through ceramic, for 20s or 40s

		- Base Dentin: 2M2 - Base Dentin: 5M3 5. - 0M1: #7505; - 2M2: #31570; - 5M3: #12490	5. - T: #L01441; - A3 Catalyst: #K27635 - Yellow: base: #K43442; - Catalisador: #K56289			
Ramos et al, 2021[21]	1. N=90 2. N=5	1. Lithium disilicate 2. GC LiSi Press inicial (GC Co) 3. 0.3mm, 1mm and 2mm 4. MT-A1 5. NR	1. Light polymerized 2. Variolink Esthetic LC, (Ivoclar Vivadent) 3. 50µm 4. Light+ 5. NR	1. - Second-generation (single-peak): Radii Plus (SDI) - Third-generation (multipeak): Valo (Ultradent) 2. 1000mW/cm² 3. - Radii Plus: NR - Valo: Standard	20s, 40s or 60s	Light polymerized through polyester strip and ceramics, of different thicknesses, for 20s, 40s or 60s
Shim et al, 2018[25]	1. N=27 2. N=9	1. Lithium disilicate ceramic and monolithic zircônia 2. – Lithium disilicate: lingotes IPS e.max Press HT (Ivoclar-	1. Dual 2. G-CEM LinkAce (GC Corporation) 3. 40µm 4. NR 5. 1604071	1. Dr’s Light (Good Doctors Co) 2. - Low: 500mW/cm² - Medium: 1000mW/cm² - High: 1500mW/cm²	20s or 60s	Light polymerized through ceramic, 2mm distance, with LED in low, medium or

		Vivadent) - Monolithic zirconia: LAVA Plus (Deutschland GmbH) 3. 1mm 4. – IPS e-max Press: HT A2 - LAVA Plus: A2-T 5. NR		4. High, medium and low irradiance		high irradiance, for 20s or 60s
Sulaiman et al, 2015[18]	1. N=200 2. N=5	1. Monolithic zirconia and zirconia core 2. – Monolithic zirconia: Prettau Anterior (Zirkonzahn); BruxZir Zirconia (Glidewell Laboratories); Wieland Zenostar (Ivoclar Vivadent); Katana (Kurary Noritake Inc)	1. Duals 2. - RelyX Ultimate (3M ESPE) - Variolink II (Ivoclar Vivadent) 3. 40µm 4. T 5. NR	1. Elipar S10 (3M ESPE) 2. 1200mW/cm² 3. NR	20s or 40s	Light polymerized through ceramics for 20s (RelyX Ultimate) or 40s (Variolink II)

	- Zirconia core: ICE Zircon (Zirkonzahn) 3. 0.5; 1; 1.5 and 2mm 4. NR 5. NR	

HT: High Translucency; LED: Light emitting diode; LPU: Light-polymerization unit; LT: Low Translucency; MT: Medium Translucency; NR: Not reported; SS: Soft-Start; T: Translucent; XP: Xtra Power.

Table 4. Characteristics of the results of the included studies

Study	Time interval between light polymerization and DC evaluation	DC assessment instrument 1. Type 2. Brand and manufacturer 3. Device resolution 4. N° of scans per spectrum 5. Absorbance peaks: - Metacrylate Carbon double boond - Aromatic Carbon double bonds	DC (%) - Experimental Groups	DC (%) – Control Group (20s)	Statistical analysis 1. Statistical tests 2.SE (p<0.05) between times 3. SE (p<0.05) between groups
Alovisi et al, 2018[22]	Immediately and after 10min	1. FTIR Spectroscopy with ATR 2. Thermo Scientific Nicolet IS10/NR 3. 6cm^{-1} 4. NR 5. - 1634cm^{-1} - 1608cm^{-1}	120s: Rely-X Ultimate: 62.9 ± 1.9[a] Panavia AS: 58.1 ± 5.2[a]	Rely-X Ultimate: 63.3 ± 2.9[b] Panavia AS: 52.8 ± 5.7[c]	1. 2-way ANOVA; Scheirer-Ray-Hare test and Mann-Whitney test with Bonferroni correction 2. P>0.05 between times 3. P<0.05 between cements
Alshaafi et al, 2014[1]	Immediately (after 100s)	1. FTIR Spectroscopy with ATR 2. Tensor 27 (Bruker Optics) 3. 8cm^{-1} 4. NR	40s: IPS Em-press Esthetic: 62.4 ± 0.3[a] IPS e.max ZirPress: 61.6 ± 0.7[a]	IPS Em-press Esthetic: 59.4 ± 0.8[b] IPS e.max ZirPress: 57.9 ± 1.0[b]	1. 2-way ANOVA (variables: time and ceramic type) and Scheffe's post-hoc test

		5. - $1638cm^{-1}$ - $1608cm^{-1}$	60s: IPS Em-press Esthetic: 63.9 ± 0.7^{a} IPS e.max ZirPress: 63.9 ± 1.0^{a}		2. p<0.05 for 20, 40 and 60s 3. p<0.05 for ceramics (p>0.05 between IPS Em-Press Esthetic and IPS e.max ZirPress for 60s)
Arrais et al, 2014[23]	Immediately	1. FTIR Spectroscopy 2. Tensor Series (Bruker Optics) 3. $4cm^{-1}$ 4. 16 5. - $1638cm^{-1}$ - $1608cm^{-1}$	40s: Rely X U100: Temperature during polymerization: **25 °C:** 45.1 ± 2.6^{a} **28 °C:** 46.8 ± 1.0^{a} **32 °C:** 47.9 ± 1.5^{a}	Maxcem Elite: Temperature during polymerization: **25 °C:** 52.4 ± 1.3^{b} **28 °C:** 59.5 ± 2.4^{b} **32 °C:** 66.2 ± 3.3^{b}	1. 2-way ANOVA (variable: temperature) 2. NR 3. NR between cements; p<0.05 between temperatures
Barutcigil et al, 2020[24]	After 24h	1. FTIR Spectroscopy 2. NR / Bruker 3. $4cm^{-1}$ 4. NR 5. - $1638cm^{-1}$ - $1609cm^{-1}$	30s: RelyX Veneer: T: 0.5mm: 85.38 ± 4.28^{akl} 1mm: 75.12 ± 11.71^{akl} 1.5mm: 69.94 ± 5.43^{akl} 2mm: 63.58 ± 5.86^{akl} HT:	RelyX U200: T: 0.5mm: 82.61 ± 5.58^{c} 1mm: 81.02 ± 1.10^{d} 1.5mm: 83.02 ± 1.60^{e} 2mm: 84.04 ± 1.46^{f} HT: 0.5mm: 80.82 ± 2.69^{g} 1mm: 80.66 ± 5.79^{h} 1.5mm: 83.06 ± 0.53^{i}	1. Kolmogorov-Smirnov and Shapiro-Wilk tests, one-way ANOVA, Tukey's HSD multiple comparison tests and independent t test 2. P<0.05 between times

			0.5mm: 81.16 ± 5.33^{akl} 1mm: 85.58 ± 3.13^{bkl} 1.5mm: 69.44 ± 12,45^{al} 2mm: 75.26 ± 8.67^{ak}	2mm: 81.06 ± 0.6^{j}	3. P<0.05 between cements; p>0.05 between thickness
Ebeid et al, 2021[5]	After 24h	1. FTIR Spectroscopy 2. NICOLET 6700/NR 3. 4cm^{-1} 4. NR 5. - 1637cm^{-1} - 1608cm^{-1}	10s: Vita Mark II: Low: 51 ± 1.68^{a} High: 54 ± 2.24^{a} SS: 59 ± 3.13^{a} Vita Enamic: Low: 49 ± 1.32^{a} High: 48 ± 1.81^{a} SS: 53 ± 2.69^{a} Cerasmart: Low: 45 ± 2.13^{e} High: 43 ± 1.91^{f} SS: 49 ± 2.54^{a}	Vita Mark II: Low: 56 ± 1.29^{b} High: 57 ± 1.78^{c} SS: 65 ± 2.72^{d} Vita Enamic: Low: 50 ± 2.93^{a} High: 51 ± 2.13^{a} SS: 57 ± 3.28^{c} Cerasmart: Low: 46 ± 2.19^{e} High: 47 ± 2.87^{f} SS: 51 ± 2.13^{a}	1. Kolmogorov-Smirnov and Shapiro-Wilk test, three-way ANOVA (variables: ceramic material, polymerization mode and time) and Tukey's multiple comparison test. 2. P>0.05 between times 3. P<0.05 for ceramic types and light polymerization mode; p>0.05 for high and low intensity modes
Faria-e-silva et al, 2017[17]	After 5min and 72h	1. FTIR Spectroscopy 2. Nicolet 6700 (Thermo Scientific)	3s: After 5min: Valo (Xtra Power):	After 5min: SmartLite Focus: 0,5mm: 61.1 ± 0.1^{f}	1. 2-way ANOVA and Tukey's post-hoc test

		3. 4cm^{-1} 4. 2 5. - 6165cm^{-1} - 6165cm^{-1}	0.5mm: 47.0 ± 1.3[a] 1mm: 42.8 ± 2.2[b] 2mm: 39.8 ± 0.6[c] After 72h: Valo (Xtra Power): 0.5mm: 61.8 ± 1.1[c] 1mm: 57.7 ± 2.1[bd] 2mm: 51.1 ± 2.5[ce]	1mm: 59.6 ± 0.5[b] 2mm: 57.8 ± 0.2[g] Valo (Standard): 0.5mm: 59.3 ± 0.8[ch] 1mm: 59.5 ± 0.9[bn] 2mm: 57.4 ± 0.3[i] After 72h: SmartLite Focus: 0.5mm: 74.0 ± 0.1[j] 1mm: 73.9 ± 0.4[bn] 2mm: 73.2 ± 1.1[cn] Valo (Standard): 0.5mm: 78.5 ± 2.4[k] 1mm: 75.9 ± 2.0[bm] 2mm: 71.7 ± 0.8[l]	2. NR 3. P<0.05 for LPU and ceramic thickness, after 5 min and after 72h; p>0.05 for resin cement and activation mode.
Jang et al, 2017[13]	After 10min and 24h	1. FTIR Spectroscopy 2. Nicolet 6700 FT-IR (Thermo) 3. 4cm^{-1} 4. 2 5. - 6165cm^{-1} - 6165cm^{-1}	120s: Rely-X ARC: After 10min: 2mm: 78.89 ± 1.10[ap] 4mm: 75.09 ± 2.07[aq] After 24h: 2mm: 86.48 ± 0.97[bp]	Rely-X ARC: After 10min: 2mm: 71.92 ± 1.02[ar] 4mm: 63.46 ± 1.71[as] After 24h: 2mm: 82.82 ± 0.94[bcr] 4mm: 75.78 ± 2.22[bcs]	1. One-way ANOVA (10min and 24h CT) and paired T test. 2. NR 3. P<0.05 between the 10min and 24h groups; P<0.05 between thickness for 20s, after 24h;

	4mm: 85.29 ± 2.27^{cq} Duolink: After 10min: 2mm: 69.62 ± 1.44^{dt} 4mm: 69.69 ± 1.20^{eu} After 24h: 2mm: 74.74 ± 1.24^{ft} 4mm: 75.56 ± 0.51^{gu} Rely-X U200: After 10min: 2mm: 65.47 ± 1.70^{jw} 4mm: 63.75 ± 1.27^{ky} After 24h: 2mm: 71.86 ± 1.88^{lw} 4mm: 69.78 ± 0.65^{my} Maxcem Elite: After 10min: 2mm: 68.31 ± 1.41^{nB} 4mm: 63.39 ± 2.96^{nC} After 24h:	Duolink: After 10min: 2mm: 62.95 ± 1.30^{ev} 4mm: 60.23 ± 1.13^{ex} After 24h: 2mm: 69.65 ± 1.45^{hiv} 4mm: 68.05 ± 1.10^{ix} Rely-X U200: After 10min: 2mm: 56.92 ± 1.53^{kz} 4mm: 49.39 ± 2.44^{kA} After 24h: 2mm: 64.28 ± 1.60^{mz} 4mm: 58.14 ± 1.69^{mA} Maxcem Elite: After 10min: 2mm: 55.84 ± 1.25^{nD} 4mm: 48.43 ± 3.11^{nE} After 24h: 2mm: 64.57 ± 1.07^{oD} 4mm: 59.50 ± 2.33^{oE}	$p>0.05$ between thickness for 120s, after 24h.

			2mm: 74.56 ± 1.69^{oB} 4mm: 70.80 ± 3.49^{oC}		
Oliveira et al, 2012[20]	After 20min	1. FTIR Spectroscopy with ATR 2. Tensor Series (Bruker Optic) /ATR: Golden Gate 3. 4cm^{-1} 4. 16 5. - 1636cm^{-1} - 1608cm^{-1}	40s: Variolink II: 1.5mm: 25 °C: 59.9 ± 2.4^{ae} 37 °C: 64.1 ± 1.8^{a} 50 °C: 72.4 ± 1.3^{a} 3mm: 25 °C: 54.5 ± 3.2^{ae} 37 °C: 63.6 ± 1.3^{b} 50 °C: 70.3 ± 1.3^{b}	Calibra: 1.5mm: 25 °C: 56 ± 1.9^{c} 37 °C: 62.4 ± 0.7^{c} 50 °C: 67.7 ± 1.3^{c} 3mm: 25 °C: 52.9 ± 1.6^{d} 37 °C: 62.9 ± 1.1^{d} 50 °C: 67.2 ± 2.6^{d}	1. 2-way ANOVA (temperature and ceramic thickness) 2. NR 3. P<0.05 between temperatures and thickness
Ozturk et al, 2005[26]	After 24h	1. FTIR Spectroscopy 2. Perkin-Elmer, série 1600/NR 3. NR 4. NR 5. - 1637cm^{-1} - 1637cm^{-1}	40s: Median: 67^{a} 25th percentis: 63.2^{b} 75th percentis: 70.5^{c}	Median: 67^{d} 25th percentis: 59.7^{e} 75th percentis: 70.7^{f}	1. Median and 25th and 75th percentis (Kruskal-Wallis) and Mann-Whitney 2. P>0.05 between times 3. Not applicable
Passos et al, 2013[19]	After 24h	1. FTIR spectroscopy with micro-ATR 2. Bruker IFS 55 3. 4cm^{-1} 4. 100 5. - 1637cm^{-1} - 1608cm^{-1}	40s: T: 0M1: 43.84 ± 3.12^{a} 2M2: 49.20 ± 0.48^{a} 5M3: 16.97 ± 2.88^{a} A3 Yellow:	T: 0M1: 40 ± 2.07^{d} 2M2: 42.57 ± 2.63^{ej} 5M3: 16.76 ± 5.64^{f} A3 Yellow:	1. One-way ANOVA (ceramic shade, cement color and time) and Tukey's multiple comparison test

			0M1: 45.10 ± 0.64^{bj} 2M2: 47.41 ± 1.98^{cd} 5M3: 23,76 ± 6,28^{cd}	0M1: 40.82 ± 1.43^{g} 2M2: 39.28 ± 4.86^{hj} 5M3: 10.70 ± 1.40^{id}	2. P<0.05 between times for all shades except 5M3-T 3. P<0.05 between the translucency and color of the ceramic
Ramos et al, 2021[21]	Immediately	1. FTIR Spectroscopy with ATR 2. IRPrestige-21, Shimadzu /ATR: DuraSamplIR II (Smiths Detection Inc) 3. 4cm^{-1} 4. 12 5. - 1637cm^{-1} - 1608cm^{-1}	40s: Valo: 0.3mm: 79.9 ± 0.2^{aq*} 1mm: 77.2 ± 1.1^{atuyA} 2mm: 76.8 ± 0.5^{bFG*} Radii Plus: 0.3mm: 77.4 ± 1.7^{cqrs*} 1mm: 78.1 ± 2.1^{dzCE} 2mm: 74.6 ± 0.5^{eGH*} 60s: Valo: 0.3mm: 80 ± 0.4^{fr} 1mm: 79.9 ± 0.9^{gfvyBCD} 2mm: 77 ± 0.9^{hFH} Radii Plus: 0.3mm: 79.4 ± 1^{iqrs} 1mm: 79.4 ± 2^{jwD}	20s: Valo: 0.3mm: 76.6 ± 1^{l*} 1mm: 75.8 ± 1.2^{mtuvxzw} 2mm: 74 ± 0.9^{nF*} Radii Plus: 0.3mm: 73.4 ± 1.7^{os*} 1mm: 76.4 ± 1.8^{oxABE} 2mm: 71.1 ± 1.2^{pGH*}	1. Three-way ANOVA (variables: thickness, time and LED) and Tukey test 2. P<0.05 between 20 and 60s for all thickness and between 40s and 60s using polywave LPU and 1mm ceramic 3. P<0.05 between LPU, thickness and time and between LPU and thickness.

			2mm: 75.7 ± 1^{kGH}		
Shim et al, 2018[25]	NR	1. FTIR Spectroscopy 2. NIR Solutions (BUCHI) 3. 4cm $^{-1}$ 4. 10 5. - 6165cm^{-1} - 6165cm^{-1}	60s: Low irradiance: Lithium disilicate: 59.62 ± 3.43^{ac} Zirconia: 58.68 ± 1.57^{ah} Medium irradiance: Lithium disilicate: 70.87 ± 1.90^{acd} Zirconia: 68.75 ± 3.73^{aj} High irradiance: Lithium disilicate: 70.23 ± 2.42^{af} Zirconia: 69.47 ± 2.16^{al}	Low irradiance: Lithium disilicate: 54.52 ± 1.93^{ac} Zirconia: 51.84 ± 2.76^{cg} Medium irradiance: Lithium disilicate: 60.71 ± 5.47^{bc} Zirconia: 56.96 ± 5.48^{ai} High irradiance: Lithium disilicate: 62.88 ± 7.26^{ae} Zirconia: 60.08 ± 4.48^{ak}	1. Levene's test, two-way ANOVA (irradiation and time; temperature and DC) and Tukey's multiple comparison test. 2. $P<0.05$ between 60 and 20s, regardless of irradiance and ceramic type 3. $P<0.05$ between irradiance and time; $p<0.05$ for LED with low irradiance for 20s for both ceramic materials; $p>0.05$ among ceramic materials with medium or high irradiance for 60s
Sulaiman et al, 2015[18]	Immediately	1. FTIR Spectroscopy with ATR 2. Frontier; Perkin Elmer/NR 3. 4cm^{-1}	40s: Variolink II: ICE Zirkon: 0.5mm: 64.11 ± 0.17^{a}	RelyX Ultimate: ICE Zirkon: 0.5mm: 60.00 ± 0.68^{o} 1mm: 59.72 ± 0.48^{r}	1. Kolmogorov-Smirnov test, two-way ANOVA (dependent

	4. 16 5. - 1638cm^{-1} - 1638cm^{-1}	1mm: 62.96 ± 0.66^{d} 1.5mm: 61.97 ± 0.52^{h} 2mm: 60.27 ± 0.40^{j} BruxZir: 0.5mm: 64.05 ± 0.30^{b} 1mm: 62.38 ± 0.76^{df} 1.5mm: 61.25 ± 0.52^{hi} 2mm: 60.45 ± 0.41^{kn} Wieland: 0.5mm: 65.51 ± 0.53^{ab} 1mm: 63.36 ± 0.41^{efg} 1.5mm: 63.06 ± 0.83^{hi} 2mm: 62.36 ± 1.09^{jn} Prettau Anterior: 0.5mm: 65.58 ± 0.56^{cb} 1mm: 64.03 ± 0.92^{dfg} 1.5mm: 64.19 ± 0.91^{hi} 2mm: 62.54 ± 0.83^{l} Katana: 0.5mm: 65.51 ± 0.31^{db} 1mm: 64.81 ± 0.68^{dfg} 1.5mm: 64.20 ± 0.85^{h} 2mm: 63.04 ± 0.74^{m}	1,5mm: 58.06 ± 0.91^{x} 2mm: 57.86 ± 0.85^{C} BruxZir: 0.5mm: 60.26 ± 0.74^{p} 1mm: 59.73 ± 0.49^{su} 1.5mm: 57.73 ± 0.77^{yz} 2mm: 55.91 ± 0.55^{C} Wieland: 0.5mm: 61.03 ± 0.43^{opq} 1mm: 59.61 ± 0.41^{tv} 1.5mm: 58.29 ± 0.62^{wAB} 2mm: 57.31 ± 0.40^{CDE} Prettau Anterior: 0.5mm: 62.78 ± 0.67^{opq} 1mm: 61.29 ± 0.37^{ruv} 1.5mm: 60.40 ± 0.43^{xzAB} 2mm: 59.53 ± 0.66^{CDE} Katana: 0.5mm: 62.78 ± 0.85^{op} 1mm: 61,37 ± 0.57^{ru} 1.5mm: 60.87 ± 1.03^{xA}	variables: irradiance, time and DC; independent variables: zirconia brand, zirconia thickness and cement type) and Tukey HSD test. 2. NR 3. P<0.05 for ceramic brand, thickness and cement type

2mm: 59.90 ± 0.63^{CD}

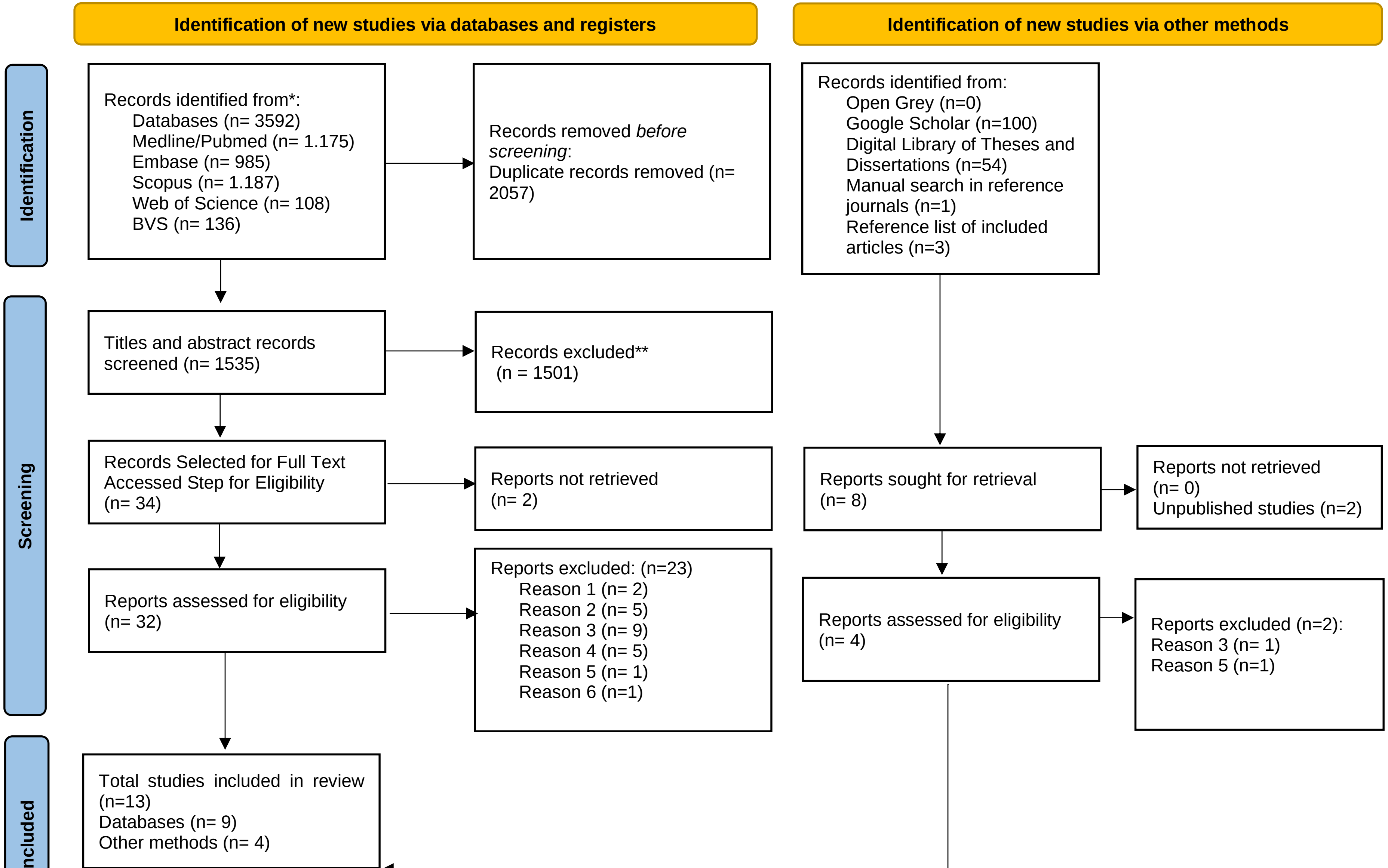
ATR: Attenuated total reflectance; DC: Degree of conversion; FTIR: Fourier Transform Infrared Spectroscopy; HT: High translucency; LED: Light emitting diode; LPU: Light-polymerizing unit; NR: Not reported; SE: Statistical significance.; SS: Soft-Start; T: Translucent; XP: Xtra Power; Lowercase or uppercase letters indicate that there is a statistical difference between the groups ($p<0.05$). *: indicates that there is a statistical difference between the LPUs at each exposure time.

Table 5. Risk of bias

Study	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**Total:**	**Risk of bias**
Alovisi et al, 2018[22]	1	1	1	0	0	0	0	1	4	Medium
Alshaafi et al, 2014[1]	0	1	1	1	0	0	0	1	4	Medium
Arrais et al, 2014[23]	0	1	1	0	0	0	0	1	3	Medium
Barutcigil et al, 2020[24]	0	1	1	1	0	0	0	1	4	Medium
Ebeid et al, 2021[5]	0	1	1	0	0	1	0	1	4	Medium
Faria-e-silva et al, 2017[17]	0	1	0	0	0	0	0	1	2	High
Jang et al, 2017[13]	0	1	1	1	0	0	0	1	4	Medium
Oliveira et al, 2012[20]	0	1	1	1	0	0	0	1	4	Medium
Ozturk et al, 2005[26]	0	1	1	1	0	0	0	1	4	Medium
Passos et al, 2013[19]	0	1	1	1	0	0	0	1	4	Medium
Ramos et al, 2021[21]	0	1	1	0	0	0	0	1	3	Medium
Shim et al, 2018[25]	0	1	1	1	0	0	0	1	4	Medium
Sulaiman et al, 2015[18]	0	1	1	1	0	0	0	1	4	Medium

(A) Division of the specimens into groups in a random manner; (B) standardization of the preparation of specimens; (C) description of the manipulation methodology of resin cement; (D) use of all materials according to the manufacturer's instructions; (E) implementation of the single operator protocol; (F) demonstration of the calculation of specimen size; (G) blinding of the operator of the testing machine; and (H) the design of the test and the calculation of the DC.[12]

Figure 1. Flowchart of study selection according to PRISMA statement.



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/

6 CONSIDERAÇÕES FINAIS

Esta revisão sugere, com bases nos estudos avaliados, que o tempo de fotopolimerização é um dos fatores que pode influenciar na TC dos cimentos resinosos, no qual um tempo maior que 20s parece proporcionar, em geral, uma maior TC de cimentos resinosos duais e fotoativados.

Além disso, os cimentos resinosos duais apresentaram, num modo geral, maiores TC em comparação aos cimentos resinosos fotopolimerizáveis. Por fim, as cerâmicas sobrepostas aos cimentos também afetaram a TC, sendo a cerâmica de dissilicato de lítio a mais favorável para uma maior TC dos cimentos resinosos.

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APÊNDICE A - Formulário de extração de dados

Artigo número: ________

Nome do avaliador: _________________________

Data: ____/_____/_____

Título (as 5 primeiras palavras):

____

Autores:

____

Fonte:

____

Ano: ________ Volume: ________ Páginas: _________

Complete com os dados finais extraídos:		
Possibilidade de artigo duplicado?	☐ Sim	☐ Não
É recomendado o contato com o autor?	☐ Sim	☐ Não
Por favor, ressalte o motivo que os autores necessitam ser contactados:	______________________________ ______________________________	

Verificação da elegibilidade do estudo

População/Exposição			
Corpos de prova com restauração indireta (resina ou cerâmica) e cimento resinoso convencional (fotopolimerizável ou dual) ou	☐ Sim	☐ Não	☐ Não está explícito

autoadesivo ou apenas com cimento resinoso?	
Pelo menos dois grupos utilizando tempos de fotopolimerização diferentes, sendo um deles de 20s?	□ Sim □ Não □ Não está explícito
N maior ou igual a 10?	□ Sim □ Não □ Não está explícito

Resultados	
Reporta a taxa de conversão sob influência do tempo de exposição de fotopolimerização?	□ Sim □ Não □ Não está explícito
Avalia o grau de conversão?	□ Sim □ Não □ Não está explícito

Desenho do estudo	
Estudo *in vitro* reportando o grau de conversão do cimento resinoso com um tempo de fotopolimerização diferente em comparação com o tempo de fotopolimerização de 20s?	□ Sim □ Não □ Não está explícito

O estudo é elegível?	
"Não" para qualquer questão classifica o artigo como inelegível, exceto para a etapa resultados. "Não está explícito" torna o estudo elegível até que a dúvida seja tirada.	□ Sim □ Não □ Talvez

Comentários:

____

____

Características do estudo

Artigo número: ___________ ID do avaliador: ______________

Tipo de estudo

Estudo *in vitro* ☐Sim ☐Não ☐Talvez

Caso os autores não classificaram o estudo corretamente, reclassifique-o: ________________________________

Característica do estudo:

Fonte de financiamento: _________________ ☐ Não está explícito

Ano que o estudo foi realizado: _________________ ☐ Não está explícito

Características da população

Nº da amostra: ________________________________

Dimensão das amostras: _________________________________

Tipo(s) de restauração(s) indireta(s) utilizada(s):	____________________ ____________________ ____________________
Tonalidade da(s) restauração(s) indireta(s):	____________________
Espessura(s) da(s) restauração(s) indireta(s) utilizada(s):	____________________ ____________________
Fabricante da restauração indireta utilizada:	____________________
Tipo de cimento(s) resinoso(s) utilizado(s):	____________________ ____________________
Fabricante(s) do(s) cimento(s) resinoso(s) utilizado(s):	____________________ ____________________
Espessura(s) do(s) cimento(s) resinoso(s) sob o material restaurador indireto:	____________________
Tonalidade do(s) cimento(s) resinoso(s):	____________________

Houve perda de amostra durante o estudo? *Se sim, qual foi a proporção do total de amostras?* *Se sim, qual explicação da perda?*	☐ Sim ☐ Não ☐ Não está explícito ______________________________
Os critérios de inclusão/exclusão estavam explícitos no estudo? *Se sim, especifique:*	☐ Sim ☐ Não ☐ Não está explícito ______________________________

Características da intervenção	
Foi utilizado 1 ou mais tipos de fotopolimerizadores?	☐ Apenas 1 ☐ Mais de um tipo Especifique qual(is):____________________________
Fabricante(s) do(s) fotopolimerizador(es):	______________________________ ______________________________
Irradiância do(s) fotopolimerizador(es):	______________________________ ______________________________ ______________________________
Houve intervalo de tempo após a “manipulação” para realização da fotopolimerização?	☐ Sim ☐ Não ☐ Não está explícito

	Se sim, especifique:____________________________
A ponta do fotopolimerizador tinha contato direto com o cimento?	☐ Sim ☐ Não ☐ Não está explícito Se não, especifique a distância da ponta fotopolimerizadora:_______________________
Tempo(s) de fotopolimerização:	_______________________________________ _______________________________________
A fotopolimerização ocorreu através do material restaurador indireto ou apenas no cimento resinoso, ou das duas formas?	☐ Através da cerâmica ☐ Foi avaliado apenas o cimento ☐ Foram realizadas as duas avaliações

Características dos resultados	
Houve intervalo de tempo para avaliação do grau de conversão após a fotopolimerização?	☐ Sim ☐ Não Se sim, especifique qual(is):______________________________
Qual o método utilizado para avaliação do grau de conversão?	especifique qual(is):_______________________________
Caso seja espectroscopia, qual o espectrofotômetro utilizado?	_____________________________________
Qual a resolução utilizada no espectrofotômetro?	_______________________________________ _______________________________________

Comentários adicionais:

____

____

____

Avaliação dos resultados	**Resultados**	**Descrição ou página do artigo onde a descrição pode ser encontrada para futura referência**
Taxa de conversão relacionado ao tempo de 20s de fotopolimerização (comparação)		
Taxa de conversão relacionado a um ou mais tempos diferentes de fotopolimerização (intervenção)		
Limitações		
Outros		

ANEXO A - REGRAS JOURNAL OF PROSTHETIC DENTISTRY

Disponível em: https://www.thejpd.org/content/authorinfo