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Faculdade de Odontologia
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Dissertação

Resinas compostas pré-aquecidas como agente de cimentação: Uma revisão sistemática de estudos *in vitro*

Laura Kroetz Fang

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Orientadora: Profª. Drª. Giana da Silveira Lima

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Notas Preliminares

A presente dissertação foi redigida segundo o Manual de Normas para Dissertações, Teses e Trabalhos Científicos da Universidade Federal de Pelotas de 2019, adotando o Nível de Descrição 4 – estrutura em Artigos, descrita no Apêndice D do referido manual.

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Resumo

FANG, Laura Kroetz. **Resinas compostas pré-aquecidas como agente de cimentação: Uma revisão sistemática de estudos *in vitro*.** 2021. Dissertação (Mestrado em Clínica Odontológica) – Programa de Pós-Graduação em Odontologia. Universidade Federal de Pelotas, Pelotas, 2021.

Uma revisão sistemática foi conduzida para investigar o desempenho de resinas compostas pré-aquecidas em comparação às resinas compostas fluidas e aos cimentos resinosos como agentes cimentantes. Este estudo também forneceu uma visão geral das propriedades relacionadas ao procedimento de cimentação com esses diferentes materiais cujo desempenho foi aqui apresentado. Foi realizada uma pesquisa de estudos que investigaram a influência da resina composta pré-aquecida utilizada como agente cimentante nas propriedades como: grau de conversão, espessura de película, adaptação marginal, viscosidade, estabilidade de cor, contração de polimerização, resistência de união e resistência à flexão. Os bancos de dados PubMed, Web of Science, Embase, Scopus e banco de dados Nacional “Biblioteca Virtual em Saúde” (BVS) foram explorados até abril de 2021, sem limite de ano. Os estudos incluídos deveriam ter pelo menos um grupo de intervenção (resina composta pré-aquecida) e um grupo controle (resina composta fluida e / ou cimentos resinosos duais ou fotopolimerizáveis). Foram excluídos os estudos que avaliaram apenas materiais atualmente indisponíveis no mercado, materiais experimentais, colagem de dispositivos ortodônticos ou compósitos pré-aquecidos como material restaurador. Dados sobre as propriedades dos agentes de cimentação à base de resina mencionados acima foram coletados. A realização de meta-análise não foi possível devido à grande heterogeneidade dos dados. Foi realizada uma análise qualitativa dos resultados, identificando os fatores associados ao desempenho das resinas compostas pré-aquecidas. Os seguintes parâmetros foram analisados para avaliar o risco de viés: cálculo do tamanho da amostra, randomização, preparação de amostra padronizada, materiais usados de acordo com as instruções do fabricante, operador cego durante o teste, relatório de dados completo, análise cega de dados e realização de análise estatística. Após a remoção das duplicatas, 703 estudos foram identificados, 34 foram selecionados para análise de texto completo e 28 artigos restantes preencheram os critérios de inclusão e foram incluídos nesta revisão sistemática. Não foram encontrados estudos clínicos que atendessem aos critérios de inclusão, de modo que a revisão ficou restrita aos estudos in vitro. Alta variabilidade foi observada nos estudos incluídos. A viscosidade e a espessura de película foram fortemente afetadas pelo aumento da temperatura para a maioria dos compósitos, no entanto não foram capazes de produzir menor espessura de filme ou viscosidade que os compósitos fluidos ou cimentos resinosos. A adaptação marginal de restaurações indiretas mostrou resultados contrastantes, pois alguns estudos observaram melhor assentamento quando cimentadas com resina composta pré-aquecida, enquanto o cimento resinoso e resina fluida proporcionaram melhor adaptação marginal em outros. Muitos resultados contraditórios também foram observados em relação à influência do pré-aquecimento da resina na contração de polimerização, grau de conversão, resistência de união e estabilidade de cor. Estudos clínicos para estabelecer resinas compostas pré-aquecidas como agente cimentante são essenciais, uma vez que de maneira geral este material apresentou resultados semelhantes em comparação às resinas compostas fluidas ou ao cimento resinoso. As resinas compostas pré-aquecidas apresentam benefícios potenciais ao serem aplicadas como agente cimentante, mas devem ser utilizadas com o conhecimento de suas limitações e dos inúmeros fatores que podem influenciar seu desempenho clínico.

Palavras-chave: Resinas compostas, Cimentos de Resina, Cimentação.

Abstract

FANG, Laura Kroetz. **Preheated composite resin as a luting agent: a systematic review of *in vitro* studies.** 2021. Dissertation (Masters in Dentistry) – Graduate Program of Dentistry. Federal University of Pelotas, Pelotas, 2021.

This systematic review was conducted to investigate the performance of preheated composite resins compared to flowable composite resins, and resin cement as luting agents. This study has also given an overview of the properties related to the luting procedure with these different materials whose performance was presented herein. A search of studies that investigated the influence of Preheated composite resin used as a luting agent on the properties such as degree of conversion, film thickness, marginal adaptation, viscosity, color stability, polymerization shrinkage, bond strength and flexural strength was conducted. PubMed, Web of Science, Embase, Scopus, and National database – "Biblioteca Virtual em Saúde" (BVS) databases were explored until April 2021 with no year limit. The included studies must have at least an intervention group (preheated resin composite) and a control group (flowable resin composite and/or dual or light-cured resin cements). Studies that evaluated only materials currently unavailable on the market, experimental materials, orthodontic devices bonding, or preheated composite as a restorative material were excluded. Data regarding resin-based luting agents' properties aforementioned were collected. A meta-analysis was not possible due to heterogeneity of data. A qualitative analysis of results was conducted, identifying factors associated to performance of preheated composite resins. The following parameters were analyzed to evaluate the risk of byas: sample size calculation, randomization, standardized sample preparation, materials used according to the manufacturer's instructions, blinded operator during the test, complete data report, blinded data analysis, statistical analysis carried out. After duplicates' removal, 703 studies were identified, 34 were selected for full-text analysis, and 28 remaining papers met the inclusion criteria and were included in this systematic review. No clinical studies that met the inclusion criteria were found, so the review was restricted to in vitro studies. High variability was observed in the included studies. Viscosity and film thickness were greatly affected by temperature increase for most of the resin composites, but still not able to produce less viscous or thinner film thickness as flowable composites or resin cements. Marginal adaptation of indirect restorations has shown contrasting results, as some studies observed better seating when cemented with preheated composite, while resin cement and flowable composites provided better marginal adaptation in others. Many contrasting results were also observed regarding the influence of preheating resin composite on polymerization shrinkage, degree of conversion, bond strength, and color stability. Clinical studies to establish preheated composite resins as a luting agent are essential since this material presented similar results in comparison with flowable composite resins or resin cement. CRD 42019120459. Preheated composite resins present potential benefits to be applied as a luting agent, but should be used with an awareness of its limitations and the countless factors that may influence its clinical performance. It must be addressed that preheating resin composite requires the purchase of a heating device, and also a learning curve due to the high technical sensitivity procedure

Keywords: Composite Resins, Resin Cements, Heating, Luting agent, Flowable composites.

Sumário

1. Introdução

As restaurações indiretas apresentam excelentes taxas de sobrevivência em médio e longo prazo, variando entre 94.7% e 96.7% para coroas metalo-cerâmicas ou totalmente cerâmicas (SAILER et al., 2015), 92% e 95% em restaurações parciais do tipo *inlays, onlays e overlays* (MORIMOTO et al., 2016) e de 84% a 100% em casos de facetas cerâmicas (MORIMOTO et al., 2016). Este tipo de restauração tem sido utilizado como alternativa às restaurações diretas em alguns casos, pois facilitam o manejo clínico quando resultados estéticos ou reabilitações amplas são necessárias. Além de permitir o uso de diferentes materiais, a abordagem indireta permite, por meio do enceramento, um melhor gerenciamento da oclusão e dimensão vertical, dos contornos anatômicos, do polimento e acabamento de todas as faces e menor sensibilidade técnica do operador (D'ARCANGELO et al., 2014; OPDAM; FRANKENBERGER; MAGNE, 2016).

Apesar do índice de falhas relativamente baixo, as descimentações, fraturas, lascamentos do material restaurador e o comprometimento estético da interface dente-restauração são algumas das causas que podem influenciar a longevidade das restaurações indiretas. A qualidade da interface adesiva e o reforço do conjunto dente/restauração têm sido associados às diferentes características dos agentes de cimentação, como o conteúdo de carga inorgânica (BARBON et al., 2019), tamanho das partículas (VALENTINI et al., 2014) e módulo de elasticidade (ADDISON; MARQUIS; FLEMING, 2007). Para proporcionar um bom desempenho do tratamento restaurador indireto, um agente de cimentação deve apresentar baixa solubilidade e contração de polimerização, alto grau de conversão, estabilidade de cor, viscosidade adequada, produzir uma fina espessura de película, que permita o correto assentamento da peça protética, e permitir um tempo adequado de trabalho (BRAGA; CESAR; GONZAGA, 2002; ILIE; SIMON, 2012).

Atualmente os materiais mais utilizados em procedimentos de cimentação adesiva são os cimentos resinosos, que são classificados de acordo com o tipo de polimerização em cimentos quimicamente ativados, cimentos de dupla polimerização ou cimentos duais e cimentos fotopolimerizáveis (D'ARCANGELO et al., 2015; SANTOS JR; SANTOS; RIZKALLA, 2009). Os cimentos resinosos fotopolimerizáveis, quando comparados à cimentos quimicamente ativados ou duais têm como vantagens clínicas o maior tempo de trabalho e melhor estabilidade de cor, mas apresentam propriedades mecânicas que irão depender da eficácia do processo de fotoativação, que pode ser influenciado pela espessura e opacidade do material restaurador, pelo tempo de aplicação da luz e ainda pela potência do equipamento utilizado (ALMEIDA et al., 2015; POLITANO; VAN MEERBEEK; PEUMANS, 2018). Os cimentos de polimerização dual foram desenvolvidos para otimizar a polimerização do material mesmo em situações clínicas em que o acesso da luz a região a ser restaurada é difícil ou quando características ópticas do material restaurador não permitem passagem de luz adequada. Para que isso seja possível, as fórmulas desses materiais contêm alto teor de coiniciadores, o faz com esses materiais apresentem como desvantagens, menor tempo de trabalho e maior susceptibilidade a alteração de cor (BRAGA; CESAR; GONZAGA, 2002; URAL et al., 2016).

Estudos *in vitro* comparando cimentos resinosos duais e fotopolimerizáveis sob restaurações de 4mm e 8mm, reportam resultados favoráveis para adesão à dentina quando cimentos fotopolimerizáveis são utilizados (KAMEYAMA et al., 2015; ÖZTÜRK et al., 2013; SARR et al., 2010). Outro experimento avaliando resistência à fadiga, de dentes com restaurações cerâmicas de 5 mm de espessura, concluiu que embora cimentos duais pareçam apresentar melhores resultados em condições extremas, os cimentos fotopolimerizáveis em combinação com a técnica de selamento imediato da dentina também podem ser indicados, mesmo em restaurações espessas (GOLDBERG; GÜTH; MAGNE, 2016). Cabe ressaltar que nestes estudos os materiais restauradores empregados eram relativamente translúcidos, com opacidade de cerca de 50%, que normalmente acabam sendo utilizados dessa forma para garantir maior naturalidade às restaurações (GOLDBERG; GÜTH; MAGNE, 2016; KAMEYAMA et al., 2015; SARR et al., 2010). No entanto, para atingir resultados adequados neste tipo de situação é essencial o uso de excelentes fontes fotoativadoras, que o tempo de exposição seja estendido por 60 segundos e repetido nas diferentes faces da restauração (ALMEIDA et al., 2015; POLITANO; VAN MEERBEEK; PEUMANS, 2018).

Materiais alternativos aos cimentos resinosos como resinas compostas fluídas e resinas convencionais pré-aquecidas também têm sido utilizados em procedimentos de cimentação. As vantagens clínicas de se empregar resinas fluídas são, principalmente, maior tempo de trabalho e menor custo. A respeito de seu desempenho como agente cimentação, as resinas fluídas parecem apresentar um comportamento semelhante à cimentos fotopolimerizáveis, em relação a solubilidade (LEAL et al., 2016) e propriedades mecânicas (BRAGANÇA et al., 2020). Em relação a resistência de união, resultados contraditórios podem ser observados (BARCELEIRO et al., 2003; PRIETO et al., 2013). O estudo que observou resultados desfavoráveis para a resina composta fluídas justificou que o teor de carga inorgânica, das resinas utilizadas no estudo era inferior ao teor de carga dos cimentos duais (PRIETO et al., 2013).

A aplicação da resina composta convencional como agente de cimentação, apesar de cada vez mais popular, não é novidade. Essa técnica já descrita em 1993, apresentava algumas preocupações como a espessura da película formada e o adequado assentamento da peça (FRIEDMAN, 1993; SCHULTE; VÖCKLER; REINHARDT, 2005). O pré-aquecimento foi então sugerido como alternativa para reduzir a viscosidade desses compósitos e consequentemente facilitar as etapas do procedimento de cimentação (ŻUŁAWNIK; CIERECH; RĄCZKIEWICZ, 2019).

Para uso clínico o pré-aquecimento das resinas compostas tem sido realizado por meio de diversos dispositivos comerciais, como o Calset (AdDent Inc., Danbury CT, EUA), ENA Heat (Micerium SpA, Avegno GE, Itália), Hotset HeatSync e o Caps Warmer (VOCO GmbH, Cuxhaven NI, Alemanha), que oferecem diferentes modalidades de aquecimento com temperaturas variando de 37°C à 69°C (LOPES et al., 2020). Quando comparada aos demais materiais citados anteriormente, as resinas compostas podem apresentar diversas vantagens como a maior diversidade de tonalidades, menor custo, menor contração de polimerização e degradação marginal e melhor desempenho mecânico devido ao seu maior teor de carga inorgânica (SCHULTE; VÖCKLER; REINHARDT, 2005).

Com disseminação da técnica, diversos estudos clínicos e laboratoriais têm investigado o comportamento da resina pré-aquecida como agente de cimentação e o efeito do pré-aquecimento nas propriedades físico-mecânicas dos compósitos (LOPES et al., 2020). Alguns dos benefícios já observados foram a melhora da resistência de união de compósitos à dentina (KRÄMER et al., 2006), aumento do grau de conversão (ACQUAVIVA et al., 2009; TOMASELLI et al., 2019), redução da viscosidade, melhor adaptação às paredes de cavidades de dentes preparados (DA COSTA et al., 2009) e menor contração de polimerização (FRÓES-SALGADO et al., 2010).

Comparando todos os agentes de cimentação mencionados, a literatura reporta que resinas *flow* apresentam espessura de película mais fina que cimentos resinosos e resinas convencionais pré-aquecidas e que o pré-aquecimento, juntamente com o uso de ultrassom para assentamento da peça, permite que algumas resinas compostas formem películas de espessura semelhantes à de alguns cimentos resinosos (MARCONDES et al., 2020). Cimentos resinosos, resinas compostas convencionais e fluídas apresentam alto potencial de polimerização para fins de cimentação (GUGELMIN et al., 2020; SCHNEIDER et al., 2020).

Embora os ensaios clínicos sejam as ferramentas mais adequadas para avaliar a eficácia dos materiais adesivos e restauradores, estudos com longos períodos de acompanhamento são difíceis de se realizar devido ao tempo, custos e até mesmo devido ao rápido desenvolvimento dos materiais odontológicos. Com isso os estudos laboratoriais são amplamente utilizados para prever o comportamento clínico dos materiais dentários. Uma recente revisão sistemática, reportou benefícios do pré-aquecimento de resinas compostas convencionais a suas propriedades física e mecânicas. No entanto, o momento nenhuma revisão se dedicou a avaliar o desempenho das resinas compostas aquecidas, como agente de cimentação, em comparação outras agentes de cimentação amplamente utilizados, como resinas compostas fluidas e cimentos resinosos. Dessa maneira, o presente trabalho tem o objetivo de reunir as evidências a respeito das propriedades de diferentes agentes de cimentação resinosos e comparar às propriedades das resinas compostas convencionais pré-aquecidas, a fim de justificar seu uso clínico como agente de cimentação. A hipótese nula a ser testada é que não haverá diferenças entre a utilização de resinas convencionais pré-aquecidas e cimentos resinosos ou resinas fluídas.

2. Objetivos

Revisar sistematicamente na literatura estudos *in vitro* comparativos das propriedades físico-mecânicas entre agentes de cimentação resinosos (resinas compostas fluídas, cimentos resinosos de polimerização dual e fotopolimerizáveis) e resinas compostas convencionais pré-aquecidas.

2.1 Objetivos específicos

- Comparar a viscosidade de resinas compostas pré-aquecidas a agentes de cimentação resinosos;
- Comparar a espessura de película de resinas compostas pré-aquecidas a agentes de cimentação resinosos;
- Comparar o grau de conversão de resinas compostas pré-aquecidas a agentes de cimentação resinosos;
- Comparar resistência de união de resinas compostas pré-aquecidas a agentes de cimentação resinosos;
- Comparar estabilidade de cor de resinas compostas pré-aquecidas à agentes de cimentação resinosos;

3. Projeto de pesquisa

3.1 Capítulo 1

Efeito da técnica *cut back* nas propriedades ópticas e mecânicas de uma cerâmica odontológica

3.1.1 Objetivos

3.1.1.2 Objetivo geral

O objetivo deste estudo *in vitro* será avaliar o efeito da técnica *cut back* nas propriedades físico-mecânicas de uma cerâmica de dissilicato de lítio.

3.1.1.3 Objetivos específicos

1. Avaliar a influência da estratificação parcial após desgate incisal, na resistência ao lascamento de uma cerâmica de dissilicato de lítio, cimentada e não cimentada em material análogo à dentina.
2. Avaliar a influência do tipo de recobrimento, total e parcial, na resistência à fratura e caracterizar o modo de falha.
3. Avaliar as propriedades ópticas dos materiais estudados.

3.1.2 Hipótese

A hipótese nula a ser testada é que técnica *cut back* não interfere nas propriedades ópticas e mecânicas dos materiais testados.

3. 1.3 Metodologia

3.1.3.1 Delineamento experimental

Será realizado um estudo experimental *in vitro* para avaliar o efeito da estratificação parcial, através da técnica *cut back*, na resistência ao lascamento de uma cerâmica vítrea de dissilicato de lítio (e.max CAD), utilizando como recobrimento uma cerâmica feldspática (Creation CC). Para isso serão confeccionados corpos de prova em cerâmica feldspática (Creation CC) e em dissilicato de lítio com espessura de 2mm, esses serão grupos controle. Também serão confeccionados corpos de prova com recobrimento total (1,2mm e.max CAD + 0,8 mm e.max Ceram = 2mm) e recobrimento parcial (com desgaste em chanfro do terço médio e incisal da restauração e.max de 2mm e recobrimento na área correspondente ao desgaste). Estes serão os grupos experimentais. Corpos de prova cimentados com um agente de cimentação adesiva á um material análago a dentina (NEMA G10)serão submetidos ao teste de lascamento da borda para avaliar a resistência à fratura por lascamento. Adisso os grupos experimentais serão avaliados quanto a resistência à fratura e parâmetros de translucidez.

Tabela1. Materiais utilizados

Material	Fabricante	Classificação	Indicação
IPS e.Max CAD	Ivoclar Vivadent (Schann, Liechtenstein)	Cerâmica vítrea de Dissilicato de Lítio	Facetas, Inlays, Onlays, Coroas anteriores e posteriores, Prótese fixa até 3 elementos.
Ácido Fluorídrico Porcelana 10%	Dentsply Sirona (Pensilvânia, EUA)	Ácido hidrofluorídrico 10%	Tratamento da superfície da cerâmica
Relyx Veneer	3M SPE (Schann, Liechtenstein)	Cimento resinoso fotopolimerizável	Cimentação
G10 - NEMA G10	International Paper (Hampton, SC, USA)	Composto a base resina epóxi reforçada por fibra de vidro	Material análogo a dentina

3.1.3.2 Grupos experimentais

No presente estudo 4 grupos serão avaliados, na forma cimentada (C) e não cimentada (NC), totalizando 8 grupos experimentais. Como controle serão utilizadas: uma cerâmica feldspática em 2mm: grupo F e uma cerâmica de dissilicato de lítio monolítica em 2mm: grupo DL. Como grupos experimentais serão utilizados espécimes de dissilicato de lítio com recobrimento total e com recobrimento parcial (técnica *cut back*): grupos RT e RP, respectivamente.

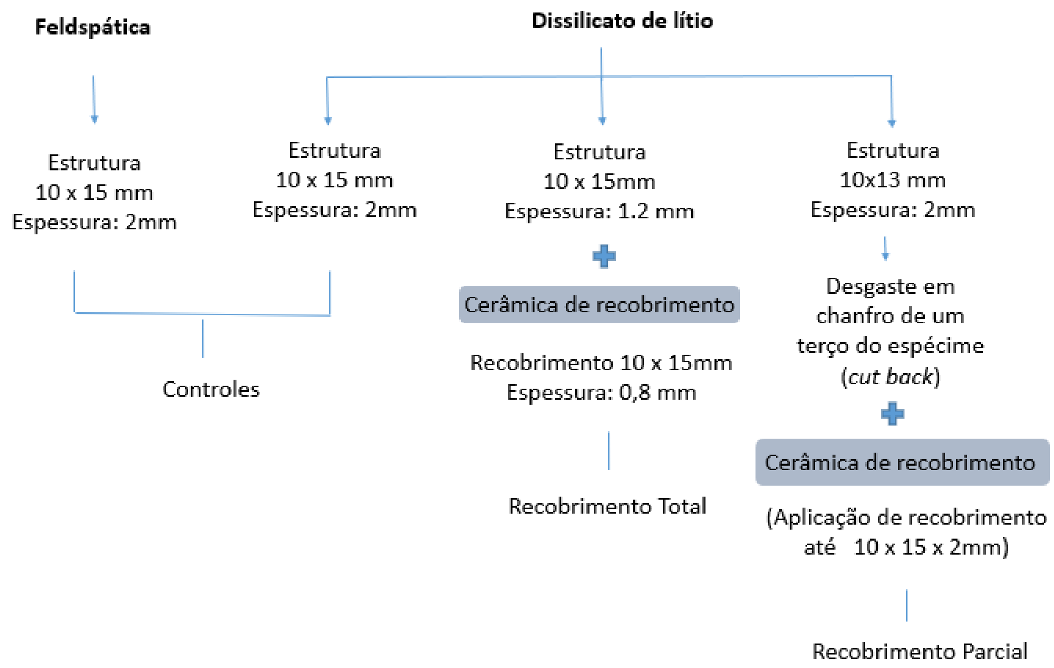

Figura 1. Grupos experimentais

3.1.3.3 Ensaios físicos

3.1.3.4 Teste Edge Chipping

Preparo dos espéciemes cerâmicos

Espécimes em barra (10x15x2mm) serão produzidos a partir de cerâmicas feldspática, pela técnica da estratificação sobre modelo em gesso (n=6 - Grupo F) e, de blocos pré sinterizados de dissilicato de Lítio, que serão seccionados em cortardeira (Isomet low speed, Bhueler, Lake Bluff, IL, EUA) sob refrigeração de água, obetendo as medidas de 10x15x1.2mm (n=6), 10x15x2mm (n=6 - Grupo DL) e 10x13x2mm.

As barras de dissilicato (10x15x1,2mm) serão utilizadas para confecção dos espécimes em bicamada, portanto, será aplicada uma cerâmica de recobrimento (Creation CC) (0,8mm), obtendo as dimensões finais de 10x15x2mm – Grupo RT. Demais barras de dissilicato (10x13x2mm), simulam a redução incisal de uma restauração e, com o auxílio de instrumentos de corte em baixa rotação também será realizado o desgate em chanfro da margem até o centro de umas das superfícias, na sequência será aplicada a cerâmica de recobrimento até à obtenção das dimensões finais de 10x15x2mm- grupo RP. O ciclo de cristalização seguirá instruções do fabricante.

Todos os espécimes serão sometidos a um processo de acabamento e polimento com lixas de carbeto de silício (Norton Indústria Brasileira, Guarulhos - SP) nas granulações 600 a 1200 afim de que as superfícies fiquem planas, lisas e com margens bem definidas. Após polimento as margens serão analisadas em microscópio óptico de magnificação 1000x (Ningbo Wason Optical Instrument Co., Ltd, Zhejiang, China). Caso necessário, o polimento será repetido.

Para a cimentação os espécimes dos grupos DL, RT e RP serão condicionados com ácido hidroflurídrico 10% por 20 seg, e o grupo F será condicionado por 90 segundos, seguido de lavagem com spray ar/água.

O material de escolha para simular a estrutura dental será uma resina epóxi reforçada por fibras de vidro, o NEMA G10 (NEMA G10, International Paper, Hampton, SC, EUA). Segundo estudos (CLELLAND et al., 2006; KELLY et al., 2010; WANG et al., 2007) este possui módulo de elasticidade similar à dentina e possibilita a união adesiva com o cimento resinoso de forma similar à obtida com a estrutura dental. A forma comercial fornecida é em barra cilíndrica (120 mm x 25 mm). Portanto, para obtenção das bases de G10 será feito o corte das barras com cortadeira de precisão utilizando um disco diamantado sob refrigeração de água, a forma final a ser obtida serão barras de 10x15mm com 5 mm de espessura. A superfície de união dos espécimes de NEMA G10 será tratada com ácido hidrofluorídrico 10% por 120s, lavagem com *spray* ar/água e aplicação de silano, por 30 segundos, seguidos de jatos de ar. (KELLY et al., 2010; TAUFER; DELLA BONA, 2019).

O cimento resinoso RelyX Veneer será aplicado na superfície cerâmica tratada e cada corpo de prova será posicionado centralizado sobre uma base de G10. Uma carga de 750 g será aplicada sobre o conjunto espécime cerâmico e base de G10 por 1 min. O excesso de cimento será removido com o auxílio de microbrush e o conjunto fotoativado por 20s em cada uma das faces laterais com aparelho fotopolimerizador (Valo, Ultradent, Victoria, Australia) com potência de 1350mW/cm².

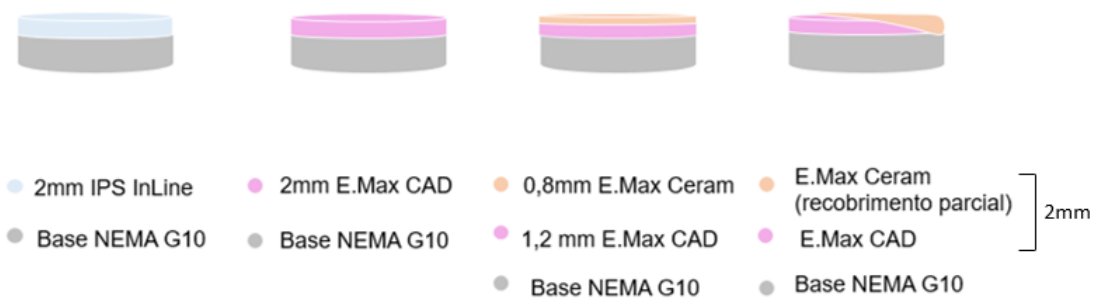

Figura 2. Desenho dos espécimes cimentados à base de material análogo a dentina.

Para verificar a resistência ao lascamento será utilizado um aparelho desenvolvido na Universidade de Passo Fundo (UPF) junto ao laboratório de engenharia mecânica da UPF. Este, consiste em uma máquina de ensaios universal onde são acoplados uma mesa de coordenadas digital e dispositivos de microscopia, mensuração e captura de imagem. Essa máquina de ensaios universal (EMIC DL-2000, EMIC Equipamentos e Sistemas de Ensaio Ltda., São José dos Pinhais, PR, Brasil) é conectada a uma haste metálica (100 mm x 16 mm) com um penetrador Vickers em sua extremidade e esse aparato ligado a uma célula de carga (HBM U9B/2KN, Alemanha) conectada a um computador portátil (Spider 8, HBM, Alemanha) para mensuração da carga aplicada (kgf) a uma velocidade de 1 mm/min. Os espécimes serão acoplados, por meio de placas de acrílico, à uma mesa de coordenadas digital com precisão de 0,001, possibilitando a movimentação milimétrica nos eixos X e Y. Com auxílio de um microscópio digital (Digital Microscope Electronic Magnifier, China), com ampliação até 1000x e controle de luminosidade, será possível registrar em computador e mensurar os lascamentos produzidos pelo penetrador tipo Vickers.

3.1.3.4 Avaliação do parâmetro de translucidez (PT)

Para esse teste os grupos F, DL, RT RP, serão avaliados na forma não cimentada (n=6 por grupo). Os parâmetros de cor serão aferidos com espectrofotômetro portátil (SP60, X-Rite, Grand Rapids, MI, USA)e a translucidez será estimada pela diferença entre as coordenadas de cores medidas sobre fundo branco (L*= 90.9, a*= 0.3, b*= 4.9) e preto (L*= 0.5, a*= 14.6, b*= -21.5) usando a seguinte a fórmula: $PT = (L_B - L_P)^2 + (a_B - a_B)^2 + (b_B - b_P)^2)^{1/2}$, onde B e P referem-se às coordenadas de cores medidas no fundos branco e preto, respectivamente. (SHARMA; WU; DALAL, 2005)

3.1.3.5 Avaliação do brilho

Os valores de brilho das cerâmicas serão mensurados com medidor de brilho (ZGM 1120 GLOSSMETER – Zehntner Testing Instruments, Sissach, Suíça). Esse aparelho mede a intensidade do reflexo de um feixe de luz, que incide na superfície do espécime, em ângulos de 20, 60 e 85º. Para as cerâmicas odontológicas, por recomendação do fabricante, serão utilizadas as medidas em 20º e 60º. O valor da intensidade da luz refletida é comparado à um valor de referência. Para a calibração do aparelho, foi utilizada uma amostra padronizada de vidro negro polido (calibrador), fornecida pelo fabricante. Serão utilizados espécimes (n=6 por grupo) sem qualquer cimentação e para cada corpo-de-prova, quatro mensurações serão realizadas, uma em cada quadrante. A média das leituras será registrada como valor da unidade de brilho para cada corpo de prova (Gloss Unit - GU).

3.1.3.6 Resistência á flexão biaxial e análise de Weidbull

Os espécimes para esse teste serão confeccionados a partir de blocos cerâmicos pré sinterizados de dissilicato de lítio usinados em formato cilíndrico (12mm), estes cilindros serão cortados em cortadeira de precisão, utilizando disco diamantado sobre refrigeração de água, em espessuras de 0,8mm e 1,5mm simulando restaurações monolíticas do tipo laminado e coroa (Grupo DL, n =30 por restauração). Outros discos de dissilicato em espessuras 0,8 mm e 1,5mm sofrerão desgaste em chanfro da margem até o centro (DESCREVER O ÂNGULO) e, na sequência essa superfície reduzida receberá a cerâmica de recobrimento (Grupo RP, n=30 por tipo de restauração). Além destes, discos com espessura de 0,6mm e 0,9mm receberão uma cerâmica de recobrimento em toda face, até que se obtenha a espessura final de 0,8mm e 1,2mm, simulando restaurações bicamadas. Os discos obtidos terão ambos os lados polidos utilizando lixas de SiC. As dimensões finais de cada amostra serão medidas com um paquímetro digital com precisão de 0,001 mm (Mitutoyo, Tóquio, Japão). O tratamento de superfície será realizado da mesma forma descrita anteriormente. Uma quantidade padrão do cimento resinoso será aplicada sob o espécime cerâmico, que será posicionado centralizado em uma plataforma de carregamento (?) e uma carga de 750g ou 5 N (?) será aplicada afim de padronizar a espessura do cimento. O excesso de cimento será removido com o auxílio de microbrush seguido fotoativado por 20s em cada uma das faces laterais com aparelho fotopolimerizador (Valo, Ultradent, Victoria, Australia) com potência de 1350mW/cm².

Para avaliar a resistência a flexão os espécimes (n = 30 por grupo) serão posicionados em uma base metálica circular com três esferas de 3,2mm de diâmetro, equidistantes, formando um plano. Um identador esférico de ponta romba de 4mm de diâmetro será acoplado à uma máquina de ensaios universais (Emic DL500; Emic, São José dos Pinhais, PR, Brasil). A carga axial será aplicacada utilizando célula de carga de 1000kgf e velocidade de 1 mm/min até ocorrer a fratura. Para cacular a resistência a flexão biaxial, serão utilizadas as seguintes fórmulas (ISO 6872):

$\boldsymbol{S} = \boldsymbol{-0},\ \boldsymbol{2387}\ \boldsymbol{P}\ (\boldsymbol{X} - \boldsymbol{Y}/\boldsymbol{d}^2)$, onde S é a tensão máxima de tração em Pascal, P é a carga total aplicada para se provocar a fratura, em Newton, e d é a espessura da amostra na origem da fratura, em mm. X e Y foram determinados pelas equações,

$\boldsymbol{X} = (\boldsymbol{1} + \boldsymbol{v})\ \boldsymbol{log}\ (\ \boldsymbol{r2}/\boldsymbol{r3}\ )^2 + [\ \underline{\boldsymbol{1} - \boldsymbol{v}}\ ]\ (\ \boldsymbol{r2}\ \boldsymbol{r3}\ )$

$\boldsymbol{X} = (\boldsymbol{1} + \boldsymbol{v})\ \boldsymbol{log}(\ \boldsymbol{r2}\ \boldsymbol{r3}\ )\ \boldsymbol{2} + [\ \boldsymbol{1} - \boldsymbol{v}\ \boldsymbol{2}\ ]\ (\ \boldsymbol{r2}\ \boldsymbol{r3}\ )\ \boldsymbol{2}\ \boldsymbol{Y} = (\boldsymbol{1} + \boldsymbol{v})\ [\boldsymbol{1} + \boldsymbol{In} + (\ \boldsymbol{r2}\ \boldsymbol{r3}\ )\ \boldsymbol{2}\ ] + (\boldsymbol{1}\_\boldsymbol{v})\ (\ \boldsymbol{r2}\ \boldsymbol{r3}\ )$

Onde v é o coeficiente de Poisson; r1 é o raio do suporte circular, em mm, r2 é o raio da área sob carga em mm; r3 é o raio da amostra, em mm; d é a espessura da amostra na origem da fratura, em mm.

A análise de Weidbull será realizada com o auxílio de um programa estatístico (programa).

3.1.3.7 Análise fractográfica

Serão selecionadas amostras mais representatias de cada teste (n=4). As áreas fraturadas terão suas superfícies analisadas com microscópio óptico (SEM – SUPRA 40, Carl Zeiss Microimaging, Tornwood, NY, USA) e posteriormente com microscópio eletrônico de varredura (MEV), para observação detalhada da origem e propagação da fratura.

3.1.3.8 Análise Estatística

O número de repetições especificadas nas metodologias acima partiu dos valores mais comumente utilizados na literatura. De posse dos resultados dos experimentos, o método estatístico mais apropriado será escolhido com base na aderência ao modelo de distribuição normal e igualdade de variância. Para todos os testes será considerado o valor $p<0{,}05$ como estatisticamente significante. Para a realização da análise estatística, será utilizado o programa estatístico SigmaStat 13.0 (Systat INC).

3.1.4. Orçamento

Tabela 2. Orçamento do estudo

Descrição	Quantidade	Preço unitário (R$)	Preço total (R$)
IPS InLine (Ivoclar Vivadent, Schann, Liechtenstein)	1	200,60	200,60
IPS e.Max Ceram HT (Ivoclar Vivadent, Schann, Liechtenstein)	1(embalagem com 5 unidades)	295,94	295,94
IPS e.Max CAD (Ivoclar Vivadent, Schann, Liechtenstein)	1	577,41	577,41
G10 - NEMA G10	1	250,00	250,00
Relyx Veneer	1	1.007,98	1007,98
Ácido Fluorídrico Porcelana 10% (Dentsply, USA)	2	29,90	59,80
Lixas de Carbeto de Silício com granulações de 600 (6un), 1200 (6un)	12	R$ 6,00	72,00
Material de laboratório (consumíveis, descartáveis)	-	500	500
Materiais de escritório	-	200	200
		TOTAL	3.140,73

3.1.5. Cronograma

O presente estudo será desenvolvido durante o período de abril de 2019 a março de 2021 e será dividido de acordo com a tabela abaixo:

Atividdade	Período																				
	2019								2020										2021		
	M	J	J	A	S	O	N	D	J	F	M	J	J	A	S	O	N	D	J	F	M
Pesquisa bibliográfica	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Qualificação do Projeto de Dissertação						X															
Confecção dos espécimes							X	X													
Parâmetros de translucidez									X												
Resistencia ao lascamento										X	X										
Resistencia a fratura											X	X									
Tabulação e análise dos dados													X	X							
Redação															X	X	X	X	X		
Apresentação da Dissertação e submissão dos artigos																				X	

4 Relatório de Trabalho de Campo

O presente relatório apresenta um breve resumo do desenvolvimento desta dissertação.

Esta dissertação foi baseada em um projeto de iniciação cientifica iniciado em 2018, que tinha como objetivo realizar uma revisão sistemática para investigar o efeito do pré-aquecimento em propriedades das resinas compostas.

Uma seleção ampla a partir de uma busca piloto, realizada em junho de 2020, resultou 138 artigos. Um levantamento sobre quais propriedades eram avaliadas e quais os materiais era utilizados foi realizada. Com os esses achados, a ideia de pesquisa foi adaptada, voltando-se para o uso de resinas aquecidas como agente de cimentação. Por fim, determinando o tema da presente dissertação.

O projeto “Efeito da técnica *cut back* nas propriedades ópticas e mecânicas de uma cerâmica odontológica" qualificado por mim em 18 de setembro de 2019, teve seu desenvolvimento interrompido por questões relacionadas à pandemia, uma vez que seriam necessárias visitas à cidade de Passo Fundo, para realização de ensaios mecânicos indisponíveis na Universidade Federal de Pelotas.

5 Artigo

Preheated composite resin as a luting agent: An in vitro systematic review and meta-analysis §

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ABSTRACT

Objective. A systematic review was conducted to investigate the performance of preheated composite resins compared to flowable composite resins, and resin cement as luting agents. This study has also given an overview of the properties related to the luting procedure with these different materials whose performance was presented herein.

Methods. A search of studies that investigated the influence of Preheated composite resin used as a luting agent on the properties such as degree of conversion, film thickness, marginal adaptation, viscosity, color stability, polymerization shrinkage, bond strength and flexural strength was conducted. PubMed, Web of Science, Embase, Scopus, and National database – "Biblioteca Virtual em Saúde" (BVS) databases were explored until April 2021 with no year limit. The included studies must have at least an intervention group (preheated resin composite) and a control group (flowable resin composite and/or dual or light-cured resin cements). Studies that evaluated only materials currently unavailable on the market, experimental materials, orthodontic devices bonding, or preheated composite as a restorative material were excluded. Data regarding resin-based luting agents' properties aforementioned were collected. A meta-analysis was not possible due to the heterogeneity of data. A qualitative analysis of results was conducted, identifying factors associated with the performance of preheated composite resins. The following parameters were analyzed to evaluate the risk of bias: sample size calculation, randomization, standardized sample preparation, materials used according to the manufacturer's instructions, blinded operator during the test, complete data report, blinded data analysis, statistical analysis carried out.

Results. After duplicates' removal, 703 studies were identified, 34 were selected for full-text analysis, and 28 remaining papers met the inclusion criteria and were included in this systematic review. No clinical studies that met the inclusion criteria were found, so the review was restricted to in vitro studies. High variability was observed in the included studies. Viscosity and film thickness were greatly affected by temperature increase for most of the resin composites, but still not able to produce less viscous or thinner film thickness as flowable composites or resin cements. Marginal adaptation of indirect restorations has shown contrasting results, as some studies observed better seating when cemented with preheated composite, while resin cement and flowable composites provided better marginal adaptation in others. Many contrasting results were also observed regarding the influence of preheating resin composite on polymerization shrinkage, degree of conversion, bond strength, and color stability. Clinical studies to establish preheated composite resins as a luting agent are essential since this material presented similar results in comparison with flowable composite resins or resin cement. CRD 42019120459.

Significance. Preheated composite resins present potential benefits to be applied as a luting agent but should be used with an awareness of its limitations and the countless factors that may influence its clinical performance. It must be addressed that preheating resin composite requires the purchase of a heating device, and also a learning curve due to the high technical sensitivity procedure.

Keywords: Composite Resins, Resin Cements, Heating, Luting agent, Flowable composites.

1. INTRODUCTION

The application of conventional composite resin as a cementing agent, although increasingly popular, is not new. This technique, already described in 1993, presented some concerns, such as the thickness of the formed film and the proper seating of the piece (1,2). Preheating was then suggested as an alternative to reduce the viscosity of these composites and consequently facilitate the steps of the cementation procedure(3).

For clinical use, preheating has been carried out using various commercial devices, such as Calset (AdDent Inc., Danbury CT, USA), ENA Heat (Micerium SpA, Avegno GE, Italy), Hotset HeatSync, and Caps Warmer (VOCO GmbH, Cuxhaven NI, Germany), which offer different heating modes with temperatures ranging from 37 ° C to 69 ° C (4). When compared to the other materials previously mentioned, composite resins can present several advantages such as greater diversity of shades, lower cost, less polymerization contraction, and marginal degradation, and better mechanical performance due to their higher content of inorganic load (2).

With the dissemination of the technique, several clinical and laboratory studies have investigated the behavior of preheated resin as a cementing agent and the effect of preheating on the physical-mechanical properties of composites (4). Some of the benefits already observed were the improvement of bond strength of composites to dentin (5), increased degree of conversion (6,7), reduced viscosity, better adaptation to prepared cavity walls (8) and lesser polymerization contraction (9).

The literature reports that flow resins have a thinner film thickness than types of resinous cement and preheated resins and that preheating, alongside the use of ultrasound for laying the part, allows some composite resins to form films of thickness similar to that of some types of cement (10). Different types of resinous cement, conventional and flowable composite resins have high polymerization potential for cementation purposes (11). Despite preheating composite resin appears to improve their mechanical and physical properties in laboratory studies (4) there is a lack of its performance as a luting agent compared to resin cement or flowable composite resin to evaluate the advantages of preheating technique. Some properties such as viscosity, film thickness, marginal adaptation, degree of conversion, polymerization shrinkage, color stability, bond strength and flexural strength; could be related to luting procedure effectiveness and should be investigated.

Thus, the objective of this systematic review was to investigate the performance of preheated composite resins compared to flowable composite resins, and resin cement as luting agents. The tested hypothesis was that there would be no statistical difference between luting agents concerning their properties.

2. METHODS

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (12). The review protocol was registered at the Prospective Register of Systematic Reviews (PROSPERO) database under the registration number CRD 42019120459.

The review question: How do preheated resins behave when used as a luting agent? was adapted from the PICO framework, as follows: **Population:** resin-based luting agents; **Intervention:** preheated resin composite, except flowable; **Comparison:** resin cement or flowable resin composite; **Outcome:** Properties related to luting procedure such as viscosity, film thickness, marginal adaptation, degree of conversion, polymerization shrinkage, color stability, bond strength and flexural strength.

2.1 Eligibility criteria

Eligible studies were studies evaluating resin-based luting agents' properties aforementioned. The studies must have at least an intervention group (preheated resin composite) and a control group (flowable resin composite and/or dual or light-cured resin cements). Studies that evaluated only materials currently unavailable on the market, experimental resin composites, orthodontic devices bonding, or preheated composite as a restorative material were excluded.

2.2 Search Strategy

The literature search was performed up to April 2021 in the following electronic databases: PubMed, Web of Science, Embase, Scopus, and a national database – “Biblioteca Virtual em Saúde” (BVS). The search strategy used in PubMed, outlined in Table 1, was adapted to the other databases. No limit regarding publication date was applied. Only papers in English, Portuguese, and Spanish were selected. Additionally, the reference list of the selected papers was hand searched for additional eligible studies.

2.3 Study selection

Literature search results were independently screened by two reviewers (LKF and CSS) using EndNote X7 software (Thomson Reuters, New York, NY, USA). If there were insufficient data, but the title or the abstract suggested any relation to inclusion criteria the study was selected for a full-text assessment. In case of disagreement, the final decision was done following consensus with a third reviewer (GSL). Full texts in agreement with the eligibility criteria were included for data extraction.

2.4 Data Extraction

Using a standardized spreadsheet in Excel format (Microsoft Corporation, Redmond, WA, USA), two independent reviewers (LKF and ABLQ) collected the following data from the included studies: materials, properties evaluated, methods employed (number of specimens, any potential aging procedure, test specifications), preheating procedure (equipment, temperature, time), main outcomes, and study’s conclusions. Missing or unclear relevant information was asked, via email, for the corresponding author. The articles were grouped by properties, including degree of conversion, film thickness, marginal adaptation, viscosity, color stability, polymerization shrinkage, bond strength, flexural strength, and elastic modulus.

2.5 Quality assessment

To perform the risk of bias and methodological quality assessment, two reviewers (LKF and CSS) evaluated each included study applying an adapted scoring system, according to previous studies (13,14). The following parameters were analyzed: sample size calculation, randomization, standardized sample preparation, materials used according to the manufacturer’s instructions, blinded operator during the test, complete data report, blinded data analysis, statistical analysis carried out. For each parameter, a "YES" or "NO" answer was given, considering the report or omission of that specified information. The risk of bias was classified according to the sum of “YES” answers received: high (1 to 3 "YES"), medium (4 to 6), and low risk of bias (7 to 8) (13,14).

2.6 Data Analysis

The variability in methodologies of the included articles resulted in several subcategories of results, making a meta-analysis unfeasible. A qualitative analysis of results was conducted, identifying factors associated with the properties and their application. The findings were grouped into categories for evaluation according to the properties related to the luting procedure as follows, viscosity, film thickness, marginal adaptation, degree of conversion, polymerization shrinkage, color stability, bond strength and flexural strength.

3. RESULTS

3.1 Search and selection

Initially, the search resulted in 1452 studies. After duplicates removal, 669 remained for title and abstract evaluation. Additionally, 4 studies were found by a manual search of the selected papers reference list. Overall, 28 studies fulfilled all eligibility criteria and were included in this systematic review. The studies excluded and the main reasons for exclusion are shown in Figure 1. No clinical study that met the inclusion criteria was found, so the review was restricted to *in vitro* studies.

3.2 Studies characteristics

The addressed properties were: viscosity (10,15–18), film thickness (8,10,17,19–25), marginal adaptation (M.Alajrash & Kassim, 2020; Magne et al., 2018; Mohammed & Majeed, 2020; Urcuyo Alvarado et al., 2020), degree of conversion (6,11,17,30–32), polymerization shrinkage (16,20,24), color stability (11,31,33,34), bond strength (25,29,35,36) and flexural strength (17,20).

3.2.1 Viscosity

A summary of the findings of the viscosity analysis is presented in Table 2. All the studies used a rheometer applying the geometry parallel plate design to evaluate the material's viscosity. Al Adhal *et. al*, 2014 and Loumprinis *et. al*, 2021 tested the materials in oscillation with a gap of 25 mm between the plates, with different rates of strain and shear applied (Al-Ahdal et al., 2014; Loumprinis et al., 2021). Coelho *et. al, 2019* and Marcondes *et. al, 2020* applied the test in the same set, with a 0,05 mm gap between the plates (10,17). Dickson *et. al, 2014* work with a 1,5 mm gap between the plates (16). Among all these studies, the temperatures analyzed were room temperature (23°C-25°C), 30°C, 37°C, 45, 54°C and 68-69°C. In all studies viscosity significantly decreased with the increase in temperature for most of the conventional composite resins tested (10,15–17). The reduction varied between studies, Al Ahdal *et. al*, 2014 observed a range from 40,8% to 92,2%, and Coelho *et. al* observed a reduction up to 93,9% at 69ºC (15,17). Contrastly, the viscosity increased as the percentage of filler loading increased (15). Even with the reduction of viscosity in response to preheating, resin composites continued to present a higher viscosity than resin cements and flow resins.

3.2.2 Film thickness

Film thickness was evaluated in 10 of the included studies and only 5 followed ISO 4049 (Table 3). Coelho *et. al, 2019* used a similar method but applied the luting agent onto a ceramic disc acid-etched, silanated, coated with adhesive, and the film thickness was measured by comparing the initial thickness of the ceramic disk, with the final thickness of the set after light-curing (17). Deb *et. al* used film thickness as a method to study flow and the diameter was the measure evaluated (20). Da Costa *et. al,* 2009 calculated the thickness/volume ratio and used it for flow analyses either (8). Sartori *et. al,* 2016 measured the film thickness by microscope images of the bond interface of the bovine dentin bonded to ceramic slabs (25). Sampaio *et. al, 2017* simulated the procedure of veneer cementation into a plastic tooth model, and the film thickness analyses were done in 3D images by tomography microcomputed (24).

In all the studies preheat the most conventional resins significantly decreased their film thickness. Even though, preheating conventional composites were not able to produce thinner film thickness as flowable composites, which also presented thinner film thickness than resin cements. One study found no linear correlation between filler content and the percentage decrease in film thickness (Blalock, 2006), while other observed a weak positive correlation between filler load and flow at both testing temperatures (20). The use of ultrasound energy significantly reduced film thickness ($p < 0.001$) of five restorative resin composites which present film thicknesses below or approximately 50 µm after the use of ultrasound: Estelite Omega, Filtek Z100, Enamel Plus HRi, VisCalor, and Gradia (10).

3.2.3 Marginal adaptation

Among the studies evaluating marginal integrity, one analyzed the bond interface of indirect composite restorations to dentin, luted with preheated resin or self-adhesive cement (29), and a better marginal sealing was observed when the preheated composite was employed. The other four investigated the marginal discrepancy of indirect restorations, by microscopic images. Indirect partial composite restorations presented better seating when luting with preheated composite (26). Mohammed *et. al, 2020* evaluated ceramic and composite overlays, while Mounajjed *et. al, 2018* and M.Alajrash *et. al, 2020* evaluated ceramic crowns (27,28,38). In these 3 studies, contrastingly, resin cement and flowable composites provided better marginal adaptation than preheated conventional composites, as presented in Table 4.

3.2.4 Degree of conversion

Degree conversion analysis was done in 6 studies (Table 5). Preheating significantly contributed to the achievement of a higher DC throughout onlays of varying thickness (6). In onlays with 3 or 4 mm, dual-cured cement and preheated composite had significantly higher DC than composite at room temperature and the light-cured resin cement. Similarly, pre-heated high viscosity resin composite showed higher DC values compared to the other light and dual resin cements in the first 5 min of polymerization reaction (32). In two studies the preheating did not affect the DC of resin composites that presented similar results compared to other resin-based luting agents (light and dual-cured) (11,17). Contrastingly, preheated resin composites also yielded the lowest DC in two studies and dual-cured resin cement the highest (30,31).

3.2.6 Polymerization shrinkage

Polymerization shrinkage was analyzed in three studies (Table 6). Deb et. al, 2011 used a one-dimension contacting transducer and readings were taken 10, 20, 30, 40, 60, 120, 300, and 480 s after light exposure (20). Dickson et. al, 2014 used a video-imaging device and the materials were analyzed continuously for 10 min after light-curing. Both reported flowable composites presenting higher shrinkage than heated composites. Contrasting results were found regarding the influence of preheating on polymerization shrinkage. While Deb et. al, 2011 found that preheating increased polymerization shrinkage for all materials tested (20), other observed that heating of the composites did not affect polymerization shrinkage (16). Sampaio *et. al*, 2017 performed scans of the specimens before and after polymerization and volumetric shrinkage was calculated by 3D rendering software. In this study, resin composites revealed higher polymerization shrinkage than light polymerized veneer cements and flowable composites regardless of the temperature (24).

3.2.5 Color stability

Table 7 present the main characteristics and findings of color stability evaluation in included studies. Color stability was determined by CIELAB and CIEDE2000 methods, using a spectrophotometer. In two studies the luting agent color stability was evaluated simulating a clinical situation, with ceramic disks attached to enamel from bovine incisors (11,33). Color parameters were assessed 24h after cementation (baseline), and subsequently at 7, 30, 90, and 180 days, and at 12 months in water storage (11) or after 10.000, and after 20.000 thermal cycles (33). Gugelmin *et. al*, 2020 reported that dual-curing resin cement had a statistically similar result to that of the light-cured resin cement and some composite resins (Z100 and Herculite) (11). In contrast, Almeida *et. al*, 2015 reported significant differences between dual-cured resin cement and light-cured materials (33). Gurdal *et. al*, 2018 cemented ceramic disks to the luting agent and Schneider et. al, 2020 used ceramic disks as an interposition between the luting material specimen and the spectrophotometer (34). These also presented conflicting results with pre-heated composite having the least color variation after storage (31) or dual-cured resin cement (34).

3.2.7. Bond strength

Five studies evaluated the influence of preheating different resin composites on bond strength to different substrates (Table 8). Of these five studies, two studies found higher bond strength mean values for a flowable resin composite (36) and resin cement (29) when compared to the cementation using preheated resin composites. Cementation using preheated resin composites yielded higher bond strength mean values than resin cement in two studies (25,35). One study (39) did not find a significant difference in the bond strength mean values of preheated resin composite and resin cement.

3.2.8 Flexural strength

Only two studies evaluated the flexural strength of preheated resin composites (Table 9). Deb *et. al*, 2011 found that for one resin composite of regular consistency and one flowable the preheating resulted in a significant increase in the flexural strength (20). Coelho *et. al*, 2019 compared feldspar ceramic discs cemented with several resin composites or with resin cement. The authors found higher biaxial flexure strength for specimens cemented with a preheated resin composite than with resin cement (17).

3.2.1 Risk of bias

The results are described in Table 10 according to the parameters considered in the study quality assessment. Most included studies presented a moderate risk of bias and five showed a high risk of bias (6,16,20,22,27). No study had a low risk of bias since the operator was not blinded during the tests in any of the studies. The data analysis was blinded in only one study, that performed the film thickness assessment by a calibrated examiner blinded to the luting system used (25). Sample size calculations were described in 4 studies (31,32,34,38). Six studies randomly allocated the specimens to different groups (11,17,25,29,36). One study did not describe the statistical analysis performed (20).

All included studies carried out the preparation of the samples in a standardized manner and were generally well described. Regarding the use of materials according to the manufacturer's recommendations, some studies that only carried out the characterization of the materials did not apply to this criteria, so they received a yes. Three studies had reported incomplete data. One of them did not report the number of specimens used (22) and the others did not describe in detail the process of preheating the resin composite (29) or the preheating time (6).

4. DISCUSSION

4.1 Viscosity, film thickness, and marginal adaptation

Concerning the use of composite resins for luting procedures the main goal of the preheating is to reduce composites' viscosity, aiming to achieve an adequate film thickness and consequently allow a good seating of the restoration (26,31). The luting material viscosity also may be related to the adhesion performance and strengthening of the restorative material since the adhesive luting system must have sufficient wettability to completely infiltrate the micro irregularities of the tooth and restoration treated surfaces, sealing superficial cracks, leading to a better dissipation of mechanical stresses (40).

In this review, all the selected studies that evaluated viscosity and film thickness reported significant decrease of viscosity and film thickness with the increase in temperatures for almost all materials tested (10,15–17). Even with heating up to 69°C, the conventional composites were significantly more viscous and produced a thicker film than all the analyzed flowable composites and most resin cement (10,15–17,37). Marcondes *et. al*, 2020 showed some brands of preheated resin composites, Essentia, Gradia, VisCalor, and Estelite Omega, which presented lower viscosity compared to light-cured resin cement, RelyX Veneer, at room temperature, and film thickness (10).

The decrease in viscosity after preheating can be influenced by filler content, filler-matrix interaction, and interlocking. Since the inorganic ceramic fillers are negligibly affected at preheating temperature ranges, interfacial interactions depend highly on the hydrodynamic force working at the particle surface (37).

There is no consensus about how to predict the behavior of composite resins when preheated (Loumprinis et al., 2021). When comparing different materials such as conventional composite resins and flowable composites, it was suggested that the lowest viscosity of the flowable composites could be attributed to its lower filler loadings. However, even just among conventional composites, a large discrepancy in the percentual of viscosity reduction is presented, ranging from 48.8% to 92.2%, which proves materials in the same category could react differently to preheating (17). Other studies did not find any trend or relationship between filler loading, viscosity, or film thickness (10,19,20,37), since some of the analyzed flowable composites had as much or more fillers than some conventional composites and still present lower viscosity.

The relevance of the viscosity during the preheating procedure or the percentual of viscosity reduction as criteria for selecting a resin for cementation has been questioned. Upon the most viscous preheated composite, some were able to produce thinner thickness film than other less viscous composites (10). The preheating of the indirect restoration and the use of ultrasound energy has been reported as alternative tools to optimize thinning film thickness (10).

Moreover, despite the higher viscosity presented by heated composite resins, an analysis of the adhesive interface showed that preheated resins, as well resin cements, were able to completely infiltrate the surface gup of acid-etched ceramic surfaces (17,29).

Concerning marginal adaptation, conflicting results were observed. Magne *et. al*, 2018 and Mohammed *et. al*, 2020 evaluated seating of indirect partial restorations, and better marginal adaptation was provided by a preheated resin and a resin cement, respectively (26,28). These differences may be related with the restorative materials since ceramics and resin composites receive different surface treatment which could promote differences in the internal space for the luting agent. Also, and more important, is to notice which resins were applied as luting agents. Mohammed et al employed Z350 XT (3M ESPE), a resin composite that even tough presented a great viscosity reduction (about 70%), remained more viscous than resin cement and other preheated resins. In contrast, Z100 (3M ESPE) employed by Magne *et. al,* 2018 present lower reduction of viscosity (about 50%), but provide thin film thickness, which makes it an adequate choice to be used in luting procedures (26).

4.2 Degree of conversion, polymerization shrinkage

As well as the results in the studies of degree of conversion selected in this review, the literature is controversial concerning the influence of temperature on the composite degree of conversion. Despite one study presents that a relatively small temperature difference can have a large and significant effect on the rate and extent of polymerization of dental resin (41), other study showed that pre-heating of resin composites does not increase the degree of conversion over time. However this advantageous effect of reduced material paste viscosity has deserved attention, since temperature rapidly drops to the physiological level upon removal from the pre-heating device (42). There seems to be an influence of the material composition on the degree of conversion evaluation, additional differences in research methodologies, light-activation mode and time, or even technical and operator variability probably are related to the divergence of results.

The comparison of the degree of conversion of pre-heated composite resins and flowable composite resins or resin cement as luting agents it must take into account a series of factors related to cementation procedure such as type of restoration, its translucency/opacity, color and thickness. In addition, the polymerization system, exclusively photoactive or dual, influences directly in the degree of conversion of the materials used in cementation.

Preheating composite resins facilitates adaptation to cavity preparation walls and decreases polymerization shrinkage. The pre-heated composite enhances degree of conversion by increased molecular mobility resulting from the temperature elevation and, thus, the postponement of diffusion-controlled propagation, reaction diffusion-controlled termination, and autodeceleration. Thereby, it allows the system to reach higher limiting conversions before vitrification. As a result, a more highly crosslinked polymer network and improved mechanical and physical properties may be anticipated from composites when they are pre-heated to temperatures above that of the room (43).The shrinkage (44) and monomer conversion are closely related factors regarding the photo-polymerization process (45) of dental materials and their composition. Improved % of degree of conversion is generally associated with a higher polymerization shrinkage. A linear relationship has been demonstrated between shrinkage strain and % of degree of conversion.

4.3 Color stability

Luting agents with improved color stability are desired for esthetic rehabilitation in order to avoid premature failure due to aesthetic reasons (31). In this review, all luting agents presented color changes, and also contrasting results about which can offer better color stability were found. These differences can be explained by variations in materials' composition and methods employed. In one study, preheated resin (Filtek Supreme) exhibited similar color variation to an amine-free dual-cured cement (Relyx Ultimate) and both presented better color stability than a light-cured resin cement (Relyx Veneer) and another dual-cured cement (Relyx Arc) (31). In another study, a dual-cured resin cement (Variolink Esthetic DC) presented better color stability performance than a composite resin (Enamel Plus HRi) (34). These findings could be associated with the proportion between photosensitizers and chemical initiators in the polymerization system of some of these dual-cured resin cements. Also, the presence of the amine in the redox system makes the cement more prone to degradation and color changes whereas the coinitiators in the light polymerization system usually are more chemically stable, tending to cause less color variation. Almeida et al did not observe significant differences in color change among all photo-cured resin materials, which may be explained by the method used, since it was the only study that evaluated ceramic disks cemented to an enamel dental structure, providing that only one layer of the luting agent was directly exposed to the aging environment, what, beyond being closer to a clinical situation, tends to minimize color changes (11,31).

4.4 Bond Strength

The bond strength of indirect restorations to dentin depends on multiple factors such as restoration material’s composition and chemical interaction between the restoration and adhesive system applied. Added to these factors, in this review, different control materials were compared to preheated composite resins, including self-adhesive and dual-cured resin cement or flowable composite resins. This heterogeneity reflects the variability of the results observed for indirect restorations bond strength to dentin. When dual-cured resin cement was used as a control material compared to different preheated resin composites, the bond strength obtained was similar to or less than composite resins. However, when compared to a self-adhesive resin luting agent, the microtensile adhesion force between dentin and resin restoration was decreased when cemented with a preheated resin composite. Mutlu et. al, 2021 concluded that preheated composite resins or flowable composites may be used on bonding glass-ceramic restorations agreeing with another study that evaluated two experimental composites with different amounts of filler simulating a conventional and a flowable composite and showed similar results for microshear bond strength (7,36). It is noteworthy that preheating will decrease the viscosity of resin composites, a characteristic that directly influences the imbrication of the material and consequently the bond strength to the dental substrate (46).

4.5 Flexural strength

Although the flexural strength of composite resin and energy density could not be affected by the pre-heating procedure (9) in the two studies included in this review, different methodologies and materials were used. According to Deb, 2011 (20) the flexural strength of Spectrum TPH and Wave were found to be statistically significantly higher with pre-heated resin, however, the other composites did not exhibit any differences. A strong negative correlation between filler load and flexural strength was reported. In the evaluation of the ceramic flexural strength, a biaxial flexural strength test was performed and Estelite Omega yielded significantly higher biaxial flexural strength than RelyX Veneer. The magnitude of the strengthening effect was higher for the preheated composite resins. Distinct composite resins respond differently to preheating and the magnitude of ceramic strengthening depends on the selection of preheated composite resin used as a luting agent (17).

5. CONCLUSION

This systematic review has some limitations that must be addressed. High variability was observed in the included studies, such as different composite resins and resin cements presenting various levels of inorganic filler for cementing diverse restorative materials (ceramic or composite discs) with different thicknesses and also evaluation methods with variability. Due to the heterogeneity of the included studies, it was not possible to perform metaanalyses. Moreover, the exclusion of two studies written in Russian and one that was not found in full-text must be observed. Clinical studies to establish preheated composite resins as a luting agent in clinical practice are necessary since this material has many advantages and presents similar results in comparison with flowable composite resins or resin cement in laboratory evaluations. Preheated resin composite has potential benefits, but should be used with an awareness of its limitations and the countless factors that may influence its clinical performance as a luting agent. Additionally, preheating resin composite requires the purchase of a heating device, clinical training, and experience, since it is a procedure with high technical sensitivity.

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Table 1. Search strategy used in PubMed

#1 Composite Resins[Mesh Terms] OR Composite resin*[tiab] OR Resin, Composite[Text word] OR Resins, Composite[Text word] OR Resin-based composite[Text word] OR "Composite Dental Resin" [Supplementary Concept] OR Resin Cements[Mesh Terms] OR Cements, Resin[Text word] OR Resin Cement[Text word] OR Cement, Resin[Text word]
#2 Preheat[tiab] OR Preheating[tiab] OR Preheated[tiab] OR Pre-heat[tiab] OR Pre-heating[tiab] OR Pre-heated[tiab] OR heating[MeSH Terms] OR warm[tiab] OR prewarm[tiab] OR prewarmed[tiab] OR pre-warm[tiab] OR pre-warmed[tiab] OR thermally-modified[tiab] OR thermally modified[tiab]
#1 AND #2

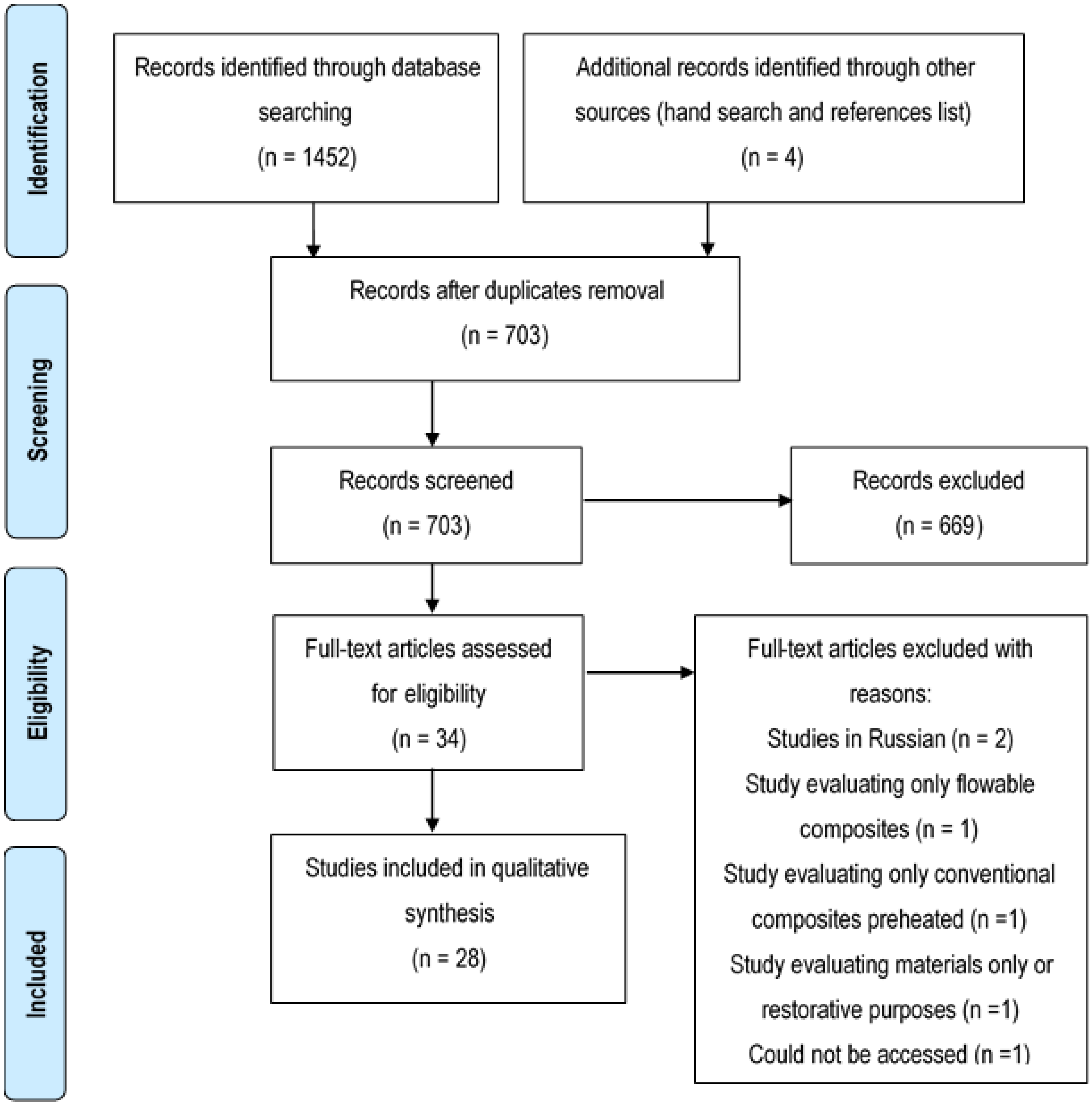

Figure 1. Flowchart of the systematic review according to PRISMA Statement

Table 2. Main characteristics and findings of selected studies considering viscosity

Author, year (Country)	Preheated composite resins	Filler Content	Flowable composites, dual or light-cured resin cements	Filler content	Preheating device, temperature	Main findings
Al-Ahdal, 2014 (United Kingdom)	Filtek Bulk Fill (3M ESPE) Tetric EvoCeram (Ivoclar Vivadent) Spectrum TPH3 (Dentsply Sirona) Ever X posterior (GC) IPS Empress Direct (Ivoclar Vivadent) Venus Pearl (Heraeus Kulzer) Esthet. XHD (Dentsply Sirona) G-aenial Anterior (GC) Filtek Supreme XTE (3M ESPE) Venus Diamond (Heraeus Kulzer) Gradia Direct Posterior (GC) G-aenial Posterior (GC)	42,5 vol% 54 vol% 57 vol% 57 vol% 58 vol% 59 vol% 60 vol% 63 vol% 63,3 vol% 64 vol% 65 vol% 65 vol%	Venus Diamond Flow (Heraeus Kulzer) G-aenial Universal Flo (GC Corporation)	41 vol% 50 vol%	Rheometer (Bohlin Instruments Ltd) 37°C	Viscosity significantly decreased with the increase in temperatures for all materials. The reduction ranged from 40,8% to 92.2%. Contrastly, the viscosity increased as the percentage of filler loading increased. Except for one Bulk Fill resin, all preheated resins at 37°C keep more viscous than flowable composites at room temperature
Coelho, 2019 (Brazil)	Filtek Z100 (3M ESPE) IPS Empress Direct (Ivoclar Vivadent) Estelite Omega (Tokuyama)	80 wt%/66 vol% 75–79 wt%/52–59 vol% 82 wt%/71 vol%	RelyX Veneer (3M ESPE)	66 wt%	Rheometer (R/S-CPS) 69°C	Viscosity at 69°C was reduced up to 93.9% for the composite resins. After heating, Empress Direct was significantly less viscous than the other two restorative composites. Resin cement at room temperature was still least viscous than preheated composites. At the end of the test, only Filtek Z100 remained less viscous than at the beginning of the analysis
Dikson, 2014 (United States)	Esthet-X (Dentsply) Filtek Supreme Ultra (3M ESPE) Durafill VS (Heraeus Kulzer)	77 wt%/ 60 vol% 78,5wt%/63,3vol% 66vol%	PermaFlo (Ultradent)	68wt%	AR2000 torsional rheometer (TA Instruments) 68°C	Among the preheated composites Esthet-X had the greatest viscosity. The flowable composite even at room temperature has the lowest viscosity. No significant difference was found between Filtek Supreme and Durafill VS

Marcondes, 2020 (Brazil)	Filtek Z350 XT (3M ESPE) TPH spectrum (Dentsply Sirona) Charisma Diamond (Heraeus Kulzer) IPS Empress Direct (Ivoclar Vivadent) Enamel Plus Hri (Micerium) Filtek Z100 (3M ESPE) Gradia (GC) Essentia (GC) Estelite Omega (Tokuyama) VisCalor (Voco)	72.5wt%/55.6vol% 75wt%/57vol% 77wt% 79.6wt% 80wt%/63vol% 80wt%/66vol% 80wt% 81wt%/65vol% 82wt%/78vol% 83wt%	Variolink Esthetic (Ivoclar Vivadet) RelyX Veneer (3M ESPE) Opallis flow (FGM)	38vol% 66wt% 72wt%	Dynamic oscillation Rheometer (R/S-CPS) 37°C and 69°C	The viscosity at 69ºC was significantly lower than at 37ºC for all materials except the flowable resin composite (p = 0.45). All resin composites heated were significantly more viscous than the flowable resin composite and Variolink Esthetic LC resin cement at either temperature. Essentia, Gradia, VisCalor, and Estelite Omega had lower viscosity compared with RelyX Veneer resin cement (at room temperature). Filtek Z350 XT showed remarkably higher viscosity than all other materials.
Loumprinis, 2021 (Germany)	Venus Pearl (Heraeus Kulzer) FiltekTM Supreme XTE (3M ESPE) Ecosite Elements PURE (DMG) VisCalor® Bulk (VOCO) Grandio®SO (VOCO) Clearfil Majestytm Posterior (Kuraray)	59 vol% 78.5 wt%/63.3 vol% 81 wt%/65 vol% 83 wt% 89 wt%/73 vol% 92 wt%/82 vol%	Ecosite Elements HIGHLIGHTS (DMG) Venus® Diamond Flow (Kulzer) FiltekTM Supreme XTE Flowable (3M ESPE) Grandio®SO Light Flow (VOCO) Clearfil Majestytm Flow (Kuraray) Grandio®SO Flow (VOCO)	65 wt%/38 vol% 65 wt%/41 vol% 65 wt%/55 vol% 76% wt 81 wt%/62 vol% 81 wt%/65 vol%	Rheometer (Physica MCR 301) 30, 37°C, 45, 54°C	Among packable materials complex viscosity generally decreased with increasing temperature. For all materials, there was a significant difference between 23 and 54°C. It can be concluded that preheating influences the complex viscosity of packable (conventional) composites

Table 3. Summary of included studies evaluating film thickness

Author, year (Country)	Preheated composite resins	Flowable composites, dual or light-cured resin cements	Preheating device, temperature and time	Main findings
Blalock, 2006 (United States)	Heliomolar RO (Ivoclar Vivadent) Esthet-X (Dentsply) Filtek Supreme (3M ESPE) Filtek A110 (3M ESPE) SureFil (Dentsply) Point 4 (Kerr) Tetric Ceram (Ivoclar Vivadent)	Flowline (Heraeus Kulzer) Aeliteflo LV (Bisco) Filtek Flow (3M ESPE) Tetric Flow (Ivoclar Vivadent) Heliomolar Flow (Ivoclar Vivadent)	Laboratory oven (Blue M Electric Co) 54°C and 60°C, stored in the oven for at least 24 hours prior to testing	No difference in thickness existed between composite resins preheated to 54ºC and 60ºC. At either temperature, there was no significant, linear correlation between filler content and the percentage decrease in film thickness. Regardless of the preheating (54°C or 60°C) all conventional composite resin was significantly greater in film thickness than flowable.
Coelho, 2019 (Brazil)	Filtek Z100 (3M ESPE) IPS Empress Direct (Ivoclar Vivadent) Estelite Omega (Tokuyama)	RelyX Veneer (3M ESPE)	Hotset (Technolife) 69°C, 5 min	Film thickness of Empress Direct and Estelite Omega were significantly greater compared with Filtek Z100. Resin cement had significantly lower film thickness than the three restorative composite resins.
da Costa, 2009 (United States)	TPH 3 (Dentsply) Esthet-X (Dentsply) Filtek Z100 (3M ESPE) Filtek Z250(3M ESPE) Premise (Kerr) Ceram X (Dentsply) Synergy (Coltene) Grandio (VOCO GmbH) Tetric Evo Ceram (Ivoclar Vivadent) Clearfil AP-X (Kuraray) Vita-l-Escense (Ivoclar Vivadent) Gradia Direct (GC) Point 4 (Kerr) Herculite XRV (Kerr) 4 seasons (Ivoclar Vivadent) Matrixx (Kulzer)	Esthet-X Flow (Dentsplay) Point 4 Flow (Kerr) Filtek Flow (3M ESPE) PermaFlo hv (Ultradent)	Calset oven (AdDent), 54°C and 68°C, 30 min	At 23°C the thickness/volume ratio (mm/cm³) of the flowable composites was significantly lower than conventional composites. The thickness/volume ratio of the conventional composites was not significantly different at 23°C, 54°C, and 68°C except for some of the resin tested, which may illustrate that warming of the composite to 54°C and 68°C only improved the flow of certain brands of the conventional composites.

	Heliomolar (Ivoclar Vivadent)			
Deb, 2011 (United Kingdom)	Spectrum TPH (Dentsply) Herculite Unideose XRV (Kerr) Heliomolar (Ivoclar Vivandent)	Wave (SDI)	Calset compule heating unit (AdDent), 60°C, 60 min	The preheating of the resin composites exhibited a significant decrease in film thickness. A significantly higher flow was observed for each of the materials when preheated to 60ºC. There was a weak positive correlation between filler load and flow at both testing temperatures (room temperature and 60°C). Although the flowability of the composites increases on warming, they are not as flowable as flowable composites.
Dionysopoulos, 2014 (Greece)	Charisma Diamond (Heraeus Kulzer) Beautifil II (Shofu) Tetric EvoCeram Bulk Fill (Ivoclar Vivadent) Filtek Supreme XT (3M ESPE) Grandio (Voco) Filtek Z250 (3M ESPE) Micro Esthetic (Bisco) Charisma (Heraeus Kulzer) Clearfil AP-X (Kuraray) Spectrum TPH (Dentsply) Heliomolar (Ivoclar Vivadent) Te-Econom Plus (Ivoclar Vivadent) Clearfil Majesty Posterior (Kuraray)	Wave (SDI) Filtek Flow (3M ESPE) Charisma Opal Flow (Heraeus Kulzer)	ENA Heat (Micerium), 54°C, 60°C, NR	The film thickness values of the composites tested are material dependent. The values of the conventional composites tested are significantly lower when heated to 54°C or 60°C compared to room temperature. All conventional composite film thickness values (room temperature or preheated to 54°C or 60°C) were significantly greater than that of the flowable materials at room temperature ($P < 0.01$).
Fahmi, 2021 (Iraq)	Filtek™ Bulk Fill (3M ESPE) Palfique LX5 (Tokuyama) ENA Hri (Micerium) Filtek™ Z350 (3M ESPE)	Relyx U200 (3M SPE) Calibra Veneer Cement (Dentsply)	Commercially available composite warmer (not specified), 64°C, 10 min	The difference between the film thickness of the conventional composites, before and after heating to 64ºC, was found to be significant. The resin cements yielded thinner film thickness than preheated composites. However, preheated resin composite still could be a good choice for adhesive cementation.
Goulart, 2013 (Brazil)	Z350XT (3M ESPE) Opallis (FGM)	Allcem (FGM)	CalSet (AdDent) 64°C, 1 min	Resin cement group showed the lower film thickness mean. Statistical difference was found between all materials including even when heated and not heated. Preheating influences composites film thickness. Although not presenting the lower film thickness, as resin cement, some composites could be used for luting indirect restorations when preheated.

Marcondes, 2020 (Brazil)	Charisma diamond (Kulzer) IPS Empress Direct (Ivoclar Vivadent) Estelite Omega (Tokuyama) Enamel plus Hri (Micerium) Filtek Z100 (3M ESPE) Filtek Z350 XT (3M ESPE) Essentia (GC) Gradia (GC) TPH spectrum (Dentsply Sirona) VisCalor (Voco)	Opallis flow (FGM) RelyX Veneer (3M ESPE) Variolink Esthetic (Ivoclar Vivadet)	HotSet (Technolife) 37°C, 69°C, 10 min	In the regular test group (no ultrasound), all preheated restorative resin composites had films thicker than 50 µm. The use of ultrasound energy significantly reduced film thickness ($p < 0.001$), the reductions varied between 21% and 49%. Five restorative resin composites had film thicknesses below or approximately 50 µm after the use of ultrasound: Estelite Omega, Filtek Z100, Enamel Plus HRi, VisCalor, and Gradia. Linear.
Sampaio, 2017 (Brazil)	Filtek Supreme Ultra Universal (3M ESPE) Empress Direct (Ivoclar Vivadent)	Empress Flow (Ivoclar Vivadent) Filtek Flow (3M ESPE) Variolink Esthetic (Ivoclar Vivadent) RelyX Veneer (3M ESPE)	Water bath 68 ± 2°C, 2.5 min	The smallest film thickness values were obtained for flowable composites and resin cements, which were significantly different from the preheated resins and resins at room temperature. Resin cements and flowable composites were not statistically different from each other.
Sartori, 2019 (USA)	Filtek Z250 (3M ESPE)	RelyX ARC (3M ESPE)	CalSet (AdDent) 69°C, 15 min	Film thickness was statistically influenced by the luting system selected. Preheated composite resin created a luting film 4,5 times thicker than dual-cure resin-cements using the same adhesive system and seating load.

NR: Not reported

Table 4. Marginal adaptation and marginal sealing main findings of included studies

Author, year (Country)	Preheated composite resins	Flowable composites, dual or light-cured resin cements	Preheating device, temperature and time	Main findings
Urcuyo Alvarado, 2020 (Mexico)	ENA Hri (SYNCA)	Relyx U200 (3M ESPE)	Heater (HRi), 39° to 55°C, 60 min	The use of preheated resin as a cementing agent of indirect composite restorations improves marginal sealing when compared to self-adhesive resin cement.
Magne, 2018 (United States)	Z100 (3M ESPE)	Relyx Ultimate (3M ESPE)	Calset (AdDent) 68°C, 5 min	The restorations seated closer to the baseline values (without any treatment or luting agent) with the resin composite compared to resin cement. The use of preheated restorative composite resin as a luting agent for inlays, onlays, and overlays can be recommended. Clinicians' concerns regarding incomplete restoration seating due to the viscosity of the composite are not justified, according to the present findings.
M.alajrash, 2020 (Iraq)	Ceramx Sphere TEC One (Dentsply)	Choice 2 Cement (Bisco) G-ænial Universal Flo (GC)	ENA heat (Micerium) 55°C, 55 min	The cementation process increased the marginal discrepancy for the 3 luting cements evaluated. Preheated composite resin produced significantly higher marginal discrepancies than the flowable composite resin or resin cement.
Mohammed, 2020 (Iraq)	Filtek Z350 XT (3M ESPE)	RelyX Ultimate (3M ESPE)	ENA heat (Micerium) 54°C, 15 min	For both lithium disilicate or reinforced composite block restorations, cementation with adhesive resin cement provided significantly better marginal adaptation than cementation with preheated composite and sonically-activated composite, with the statistically non-significant difference between the latter two cementation protocols.
Mounajjed, 2017 (Czech Republic)	ENA Hri (Micerium)	RelyX Ultimate (3M ESPE) Harvard PremiumFlow Cement (GmbH)	ENA heat (Micerium) 55°C, 60 min	Preheated resin had a significantly higher marginal discrepancy value than flow cement (P=.031). No significant differences were found between the resin cement tested (P=1.000) or between and Relyx Ultimate and ENA (P=.075).

Table 5. Summary of included studies evaluating the degree of conversion (DC)

Author, year (Country)	Preheated composite resins	Flowable composites, dual or light-cured resin cements	Preheating device, temperature and time	Light-curing unit	Restoration material	DC method	Main findings
Acquaviva, 2009 (Italy)	Venus (Heraeus)	Calibra (Dentsplay); Variolink II (Ivoclar Vivadent)	CalSet (AdDent) 54°C, NR	Halogen lamp Swiss Master Light1 (EMS, Neun, Switzerland) applying three different curing modalities: (a) 1200 mW/cm² for 40 s (b) 800 mW/cm² for 60 s and (c) 400 mW/cm² for 120 s	Onlays of different thicknesses (2, 3, and 4 mm) with Signum (Heraeus)	24h after the polymerization procedure, the onlays were detached from the slide and the superficial cement DC was quantified using a micro-Raman spectrometer (Dilor HR LabRam) at 50x magnification with an exposure time of 60 s	Preheating significantly improved the performance of the light-curing composite under onlays of great thickness. Using a pre-heated micro-hybrid composite or dual-curing material reduced the influence of the restoration thickness on the DC
Coelho, 2019 (Brazil)	Filtek Z100 (3M ESPE); IPS Empress Direct (Ivoclar Vivadent); Estelite Omega (Tokuyama)	RelyX Veneer (3M ESPE)	Hotset (Technolife) 69°C, 5 min	LED curing unit (Radii; SDI); Irradiance 1200 mW/cm2) for 40 s	Ceramic disks (0.8 ± 0.1 mm thickness) simulating monolithic veneer restorations (Vitablocs Mark II A1C for CAD-CAM, Vita Zahnfabrik)	FTIR equipped with an attenuated total reflectance diamond device was used to evaluate the DC for the unpolymerized material and the bonded ceramic specimens with the luting agent layer facing the diamond device	DC was similar between all the resin-based agents tested (p = 0.161)
de Jesus, 2020 (Brazil)	Filtek Z350 XT (3M ESPE)	Filtek Z350 XT Flow (3M ESPE); RelyX ARC (3M ESPE); RelyX Veneer (3M ESPE)	Oven (not specified), 68 ± 1 °C, 30 min	LED curing unit (Bluephase G2, Ivoclar Vivadent); Irradiance 1218 mW/cm² for 40 s	Lithium-disilicate ceramic disks (Ø 10 mm, 1.5 mm thickness) with different translucencies (IPS e.max Press, Ivoclar-Vivadent):	FTIR using a spectrometer equipped with an attenuated total reflectance diamond device. For each luting agent, the DC was determined without and with each lithium-disilicate disk interposition	Significantly different DC values were observed among the luting composite materials for all different translucencies evaluated. The dual-cured resin cement showed the highest DC%, followed by the light-cured resin cement, flowable resin, and preheated composite, which presented the lowest DC%.

Gugelmin, 2020 (Brazil)	Filtek Z100 (3M ESPE); Herculite (Kerr); Durafil (Kulzer)	AllCem Veneer (FGM); AllCem (FGM)	Ena Heat (Micerium) 55°C, 10 min	LED curing unit (Radii-Cal, SDI); Irradiance 1200 mW/cm² for 40 s	0.8-mm-thick lithium-silicate glass-ceramic laminates (Suprinity, shade B2-HT, Vita)	Micro-Raman spectroscopy (Senterra Bruker) with a resolution of 4 cm^{-1} and 32 readings at 4,000 to 800 cm^{-1}	There were no significant differences (p=0.127) among the materials tested. The heating of the composite resins did not affect their DC
Schneider, 2020 (Brazil)	Filtek Supreme (3M ESPE)	RelyX ARC (3M ESPE); RelyX Ultimate (3M ESPE); RelyX Veneer (3M ESPE)	Laboratory Oven *not specified 68 ± 1 °C, 30 min	LED light-curing unit was used (Bluephase G2; Ivoclar Vivadent); Irradiance 1218 mW/cm² for 40 s	1.5-mm-thick ceramic (e.max Press HT)	FTIR using a spectrometer equipped with an attenuated total reflectance diamond device with direct light exposure or with interposition of ceramic between the luting material and light	With ceramic interposition, the conventional dual-cured resin cement (ARC) produced the highest DC and preheated composite the lowest. Despite that, all the tested materials presented high curing potential for luting purpose
Tosco, 2021 (Italy)	Hri (Micerium)	Hri Flow (Micerium); Nexus Third Generation Light-cured (Kerr); Nexus Third Generation – Dual-cured (Kerr); RelyX Veneers (3M ESPE); Relyx Ultimate (3M ESPE); Relyx U200 (3M ESPE)	Ena Heat (Micerium) 55°C, 10 min	Elipar DeepCure S light (3M ESPE); Irradiance of 1470 mW/cm² applying 2 different curing protocols: P1 - samples were cured for 40 s; P2 - samples were cured for 5 s, and after 20 s, cured again for additional 40 s	Composite disk (Filtek Supreme, 3M ESPE) of 2 mm of thickness and 25.0 mm of diameter was interposed between the tip of the lamp and the resin cement sample	FT-NIR spectrometer, operating in the 10000–4000 cm^{-1} spectral range of unpolymerized materials and cured samples following the protocol P1 or P2. NIR spectra of the same samples were also collected after 1, 2, 7, 14 and 28 days	The obtained results showed that ~ 50% of the polymerization reaction of light-curing materials occurred during the first 5 min, with the flow resin composite and the pre-heated high viscosity resin composite showing higher DC values compared to the other light and dual resin cements

NR: Not reported; FTIR: Fourier-transform infrared spectroscopy

Table 6. Polymerization Shrinkage

Author, year (Country)	Preheated composite resins	Flowable composites, dual or light-cured resin cements	Preheating device, temperature and time	Main findings
Deb, 2011 (United Kingdom)	Spectrum TPH (Dentsply) Herculite Unideose XRV (Kerr) Heliomolar (Ivoclar Vivandent) Filtek P60 (3M ESPE)	Wave (SDI)	Calset Composite Warmer (AdDent), 60min	The preheating increased polymerization shrinkage for all materials tested. The flowable composite exhibited significantly higher shrinkage than conventional composites. There was a positive correlation between filler load and shrinkage.
Dikson, 2014 (USA)	Esthet-X (Dentsply) Filtek Supreme Ultra (3M ESPE) Durafill VS (Heraeus Kulzer)	PermaFlo (Ultradent)	Calset Composite Warmer (AdDent), 68°C	For volumetric shrinkage, significant differences was found between groups based on composite ($P < 0.01$) but not temperature ($P = 0.254$), with no significant interaction ($P = 0.425$). PermaFlo demonstrated the highest polymerization shrinkage (%). The heating of the composites did not affect polymerization shrinkage, also all the preheated resins showed less polymerization shrinkage than flowable composites.
Sampaio, 2017 (Brazil)	Filtek Supreme Ultra Universal (3M ESPE) Empress Direct (Ivoclar Vivadent)	Empress Flow (Ivoclar Vivadent) Filtek Supreme Flow (3M ESPE) Variolink Esthetic (Ivoclar Vivadent) RelyX Veneer (3M ESPE)	Water bath, 68 ± 2°C, 2.5 min	Resin composites regardless of the temperature revealed a higher percentage of shrinkage (2.1%) than the remaining groups (1.5%). Light polymerized veneer cements and flowable composite resins were not statistically different. Variolink Esthetic showed the smallest percentage shrinkage (1.03%) and Filtek Supreme the largest (2.44%).

Table 7. Color Stability

Author, year (Country)	Preheated composite resins	Flowable composites, dual or light-cured resin cements	Preheating device, temperature and time	Main findings
Almeida, 2015 (Brazil)	Filtek Z350 XT (3M ESPE)	RelyX ARC (3M ESPE) RelyX Veneer (3M ESPE) Filtek Z350 Flow (3M ESPE)	Incubator, 60°C, 30 min	The dual-polymerizing cement had the highest color variation among all luting agents. No significant differences were found in color variation among the light-polymerizing materials.
Gugelmin, 2020 (Brazil)	Filtek Z100 (3M ESPE) Herculite (Kerr) Durafill (Kulzer)	AllCem Veneer (FGM) AllCem (FGM)	Ena Heat (Micerium) 55°C, 10 min	Dual-cured resin cement had a statistically similar result to that of the light-cured resin cement and some composite resins (Z100 and Herculite, at room temperature and pre-heated).
Gurdal, 2018 (Turkey)	Enamel Plus Hri (Micerium)	Variolink Esthetic LC (Ivoclar Vivadent) Variolink Esthetic DC (Ivoclar Vivadent)	ENA Heat (Micerium) 55°C, NR	The dual-polymerizing resin cement showed significantly lower ΔE values than the preheated composite resin (P=.003). Newly developed resin cements may offer better color stability than composite resins.
Schneider, 2020 (Brazil)	Filtek Supreme (3M ESPE)	RelyX ARC (3M ESPE) RelyX Ultimate (3M ESPE) RelyX Veneer (3M ESPE)	Laboratory Oven (Not specified), 68 ± 1 °C, 30 min	Amine-free dual-activated material was able to reduce color difference when compared to that materials formulated with the amine component. Pre-heated composite produced the least color variation after storage.

NR: Not reported

Table 8. Summary of studies included that evaluated bond strength of preheated composite resins.

Author, year (Country)	Preheated composite resins	Flowable composites, dual or light-cured resin cements	Preheating device, temperature and time	Main findings
Demay, 2016 (Brazil)	Filtek™ Z100 (3M ESPE)	RelyX ARC (3M ESPE)	Composite heater (Calset, AdDent) 54°C; 5 min	There is no significant difference in the µTBS mean value of a preheated resin composite and a resin cement for the cementation of a resin composite block with up to 4 mm.
Goulart, 2018 (Brazil)	Filtek™ Z250 XT (3M ESPE) Venus (Kulzer)	RelyX ARC (3M ESPE)	Digital wax heater (SJK) 64°C; 5 min	A higher µTBS mean value was found when luting 2 mm resin composite discs with preheated Filtek™ Z250 XT than the resin cement. For 4 mm resin composite discs, luting with preheated Venus showed a higher µTBS mean value than the resin cement.
Mutlu, 2020 (Turkey)	Enamel Plus HRI (Micerium)	G-ænial Universal Flo (GC) Herculite XRV Ultra Flow (Kerr) Vertise Flow (Kerr) Variolink Esthetic DC (Ivoclar) G-CEM LinkForce (GC) Panavia V5 (Kuraray Noritake) Maxcem Elite Chroma (Kerr)	Heating unit (ENA Heat; Micerium) 55ºC; N.I.	No significant difference was observed for the SBS mean value of the preheated composite resin compared with the values of the majority of the materials tested. Only G-ænial Universal Flo exhibited a higher SBS mean value than the preheated composite resin for the cementation of a 3 mm lithium disilicate ceramic disc.
Sartori, 2016 (USA)	Filtek™ Z250 XT (3M ESPE)	RelyX ARC (3M ESPE) Clearfil Esthetic Cement (Kuraray) RelyX Unicem 2 Automix (3M ESPE)	Composite heater (Calset, AdDent) 68ºC; 15 min	The highest µTBS mean value was obtained when 8 mm ceramic slabs were cemented with the preheated composite than with the resin cements.
Urucuyo Alvarado, 2020 (Mexico)	ENA HRi (SYNCA)	Relyx U200 (3M ESPE)	Composite heater (ENA Heat, Micerium) 39ºC; 60 min	A higher µTBS mean value was observed when 5 mm resin composite restorations were cemented with resin cement than with preheated resin composite.

N.I.: Not informed; µTBS: Microtensile bond strength; SBS: Shear bond strength.

Table 9. Summary of studies included that evaluated flexural strength of preheated composite resins.

Author, year (Country)	Preheated composite resins	Flowable composites, dual or light-cured resin cements	Preheating device, temperature and time	Main findings
Coelho, 2019 (Brazil)	Filtek Z100 (3M ESPE) IPS Empress Direct (Ivoclar Vivadent) Estelite Omega (Tokuyama)	RelyX Veneer (3M ESPE)	Composite heater (Hotset, Technolife) 69°C 5 min	The higher biaxial flexure strength was yielded when 0.8 mm feldspar ceramic discs were bonded with Estelite Omega than with the resin cement. The magnitude of the strengthening effect was higher for the preheated composite resins.
Deb, 2011 (United Kingdom)	Spectrum TPH (Dentsply) Herculite Unideose XRV (Kerr) Heliomolar (Ivoclar Vivandent) Filtek P60 (3M ESPE)	Wave Flow (SDI)	Composite heater (CalSet, AdDent) 60ºC N.I.	Of the tested composites, only the flexural strengths of Spectrum TPH and Wave were significantly higher with preheating. A strong negative correlation between filler load and flexural strength was reported.

N.I.: Not informed

Table 10. Risk of bias assessment of included studies

Study	Sample size calculation	Randomization	Standard sample	Manufacturer's instructions	Blinded operator	Complete data report	Blinded data analysis	Statistical analysis	Risk of bias
Acquaviva, 2009	N	N	Y	N	N	N	N	Y	High
Al-Ahdal, 2014	N	N	Y	Y*	N	Y	N	Y	Moderate
Almeida, 2015	N	N	Y	Y	N	Y	N	Y	Moderate
Blalock, 2006	N	N	Y	Y*	N	Y	N	Y	Moderate
Coelho, 2019	N	Y	Y	N	N	Y	N	Y	Moderate
da Costa, 2009	N	N	Y	Y*	N	Y	N	Y	Moderate
de Jesus, 2020	N	N	Y	Y	N	Y	N	Y	Moderate
Deb, 2011	N	N	Y	Y	N	Y	N	N	High
Demay, 2016	N	N	Y	Y	N	Y	N	Y	Moderate
Dickson, 2014	N	N	Y	N	N	Y	N	Y	High
Dionysopoulos, 2014	N	N	Y	Y*	N	Y	N	Y	Moderate
Fahmi, 2021	N	N	Y	Y	N	N	N	Y	High
Goulart, 2013	N	N	Y	Y	N	Y	N	Y	Moderate
Goulart, 2018	N	Y	Y	Y	N	Y	N	Y	Moderate
Gugelmin, 2020	N	Y	Y	Y	N	Y	N	Y	Moderate
Gurdal, 2018	Y	N	Y	N	N	Y	N	Y	Moderate
Loumprinis, 2021	N	N	Y	Y*	N	Y	N	Y	Moderate
M. Alajrash, 2020	N	N	Y	N	N	Y	N	Y	High
Magne,2018	N	N	Y	Y	N	Y	N	Y	Moderate
Marcondes, 2020	N	N	Y	Y*	N	Y	N	Y	Moderate

Mounajjed, 2018	Y	N	Y	Y	N	Y	N	Y	Moderate
Mohammed, 2020	N	N	Y	Y	N	Y	N	Y	Moderate
Mutlu, 2020	N	Y	Y	Y	N	Y	N	Y	Moderate
Sampaio, 2017	N	N	Y	Y	N	Y	N	Y	Moderate
Sartori, 2016	N	Y	Y	Y	N	Y	Y	Y	Moderate
Schneider, 2020	Y	N	Y	Y	N	Y	N	Y	Moderate
Tosco, 2021	Y	N	Y	Y	N	Y	N	Y	Moderate
Urcuyo Alvarado, 2020	N	Y	Y	Y	N	N	N	Y	Moderate

Legend: N=NO / Y=YES; * No procedure performed to follow manufacturer's recommendation

6 Considerações Finais

Estudos clínicos para estabelecer resinas compostas pré-aquecidas como agente cimentante na prática clínica são necessários uma vez que este material apresenta muitas vantagens e apresenta resultados semelhantes em comparação com resinas compostas fluidas ou cimento resinoso em avaliações laboratoriais. A resina composta pré-aquecida apresenta benefícios potenciais, mas deve ser utilizada com o conhecimento de suas limitações e dos inúmeros fatores que podem influenciar seu desempenho clínico como agente cimentante.

7 Referências

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