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Influence of modeling agents on composite resin properties

Influência dos agentes modeladores nas propriedades da resina composta

Influencia de los agentes de modelado en las propiedades de la resina compuesta

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ABSTRACT

Objective: Assess influence of the use of modeling agents for composite resins during the incremental technique on the properties of color change (∆E), microhardness and surface roughness of this material. **Methods:** The review is registered in PROSPERO under number CRD42021238167. In vitro studies that evaluated at least the color properties of composite resins manipulated with some modeling agent, either a modeling liquid or an adhesive system were selected. The electronic searches took place in PubMed/MEDLINE, Scopus and Web of Science. **Results:** 6,761 articles were obtained, six were selected according to the eligibility criteria. The color change was reduced using Adper™ Scotchbond™ Multi-Purpose Adhesive even after storage in red wine for 6 months (p = 0.00001; Mean Difference: -7.04; CI: -8.64 to -5.44) and for 12 months (p = 0.00001; Mean Difference: -8.55; CI: -10.88 to -6.21), when compared to the control group. No significant differences were observed in microhardness and surface roughness with the use of modeling agents compared to the control group. **Final considerations:** The use of modeling agents for composite resin with a hydrophobic composition helps to maintain the color stability of the restoration without affecting microhardness and surface roughness.

Keywords: Composite resins, Dental materials, Esthetics dental.

RESUMO

Objetivo: Avaliar a influência do uso de agentes modeladores para resinas compostas durante a técnica incremental nas propriedades de mudança de cor (∆E), microdureza e rugosidade superficial deste material. **Métodos:** A revisão está registrada no PROSPERO sob o número CRD42021238167. Foram selecionados estudos in vitro que avaliaram pelo menos as propriedades de cor de resinas compostas manipuladas com algum agente modelador, seja um líquido modelador ou um sistema adesivo. As buscas eletrônicas ocorreram no PubMed/MEDLINE, Scopus e Web of Science. **Resultados:** Foram obtidos 6.761 artigos, sendo seis selecionados de acordo com os critérios de elegibilidade. A alteração de cor foi reduzida com o uso do Adesivo Multi-Purpose Adper™ Scotchbond™ mesmo após armazenamento em vinho tinto por 6 meses (p = 0.00001; Diferença Média: -7.04; CI: -8.64 to -5.44) e por 12 meses (p = 0.00001; Diferença Média: -8.55; CI: -10.88 to -6.21), quando comparado ao grupo controle. Não foram observadas diferenças significativas na microdureza e rugosidade superficial com o uso de agentes modeladores em comparação ao grupo controle. **Conclusão:** A utilização de agentes modeladores com composição hidrofóbica para

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resina composta auxilia a manter a estabilidade da cor da restauração sem afetar a microdureza e rugosidade superficial.

Palavras-chave: Resinas compostas, Materiais dentários, Estética dentária.

RESUMEN

Objetivo: Evaluar la influencia del uso de agentes modelantes para resinas compuestas durante la técnica incremental sobre las propiedades de cambio de color (∆E), microdureza y rugosidad superficial de este material. **Métodos:** La reseña se encuentra registrada en PROSPERO con el número CRD42021238167. Se seleccionaron estudios in vitro que evaluaran al menos las propiedades de color de resinas compuestas manipuladas con algún agente modelador, ya sea un líquido modelador o un sistema adhesivo. Las búsquedas electrónicas se realizaron en PubMed/MEDLINE, Scopus y Web of Science. **Resultados:** De 6.761 artículos, seis fueron seleccionados según los criterios de elegibilidad. El cambio de color se redujo utilizando el adhesivo multiusos Adper™ Scotchbond™ después del almacenamiento en vino tinto durante 6 meses (p = 0,00001; diferencia de medias: -7,04; IC: -8,64 a -5,44) y durante 12 meses (p = 0,00001; Diferencia de medias: -8,55; IC: -10,88 a -6,21), en comparación con el grupo control. No se observaron diferencias significativas en la microdureza y rugosidad de la superficie en comparación con el grupo control. **Conclusión:** Agentes modeladores para resina compuesta con composición hidrófoba ayudan a mantener la estabilidad del color de la restauración sin afectar la microdureza y rugosidad de la superficie.

Palabras clave: Resinas compuestas, Materiales dentales, Estética dental.

INTRODUCTION

Direct restorations made with composite resin have been the priority choice for the treatment of esthetic problems in relation to the shape and color of teeth, mainly due to improvements in adhesive technology in dentistry (ROSA WL, et al., 2015; WOLFF D, et al., 2010). In addition, a lower cost compared to indirect procedures combined with the use of minimal intervention technique facilitates the choice of this material (NAHSAN FP, et al., 2012; COELHO-DE-SOUZA FH, et al., 2015).

However, the skill of the professional and the physical properties of the material, including its manipulation characteristics, are extremely important to obtain an excellent final result (ARAUJO FS, et al., 2018). Therefore, the use of modeling agents emerged as an alternative to improve the adaptation and manipulation of the composite resin, facilitating the construction of the restoration (BARCELLOS DC, et al, 2008). The use of modeling liquids reduces the surface tension of the composite, in addition to penetrating any porosity created during the realization of the incremental technique, thus helping to minimize defects in the body of the restoration (BARCELLOS DC, et al, 2008; MÜNCHOW EA, et al., 2016).

Adhesives have also been used as modeling agents for composites, as their use eliminates the need for an additional material during restoration (BARCELLOS DC, et al, 2008; MÜNCHOW EA, et al., 2016; KUTUK ZB, et al., 2020). However, despite the facility of using modeling agents during the restoration, concerns about the likely negative effects of this material on the composite resin emerged and, therefore, several in vitro studies were carried out that evaluated the properties of composites manipulated with modelingagents (ARAUJO FS, et al., 2018; MÜNCHOW EA, et al., 2016; KUTUK ZB, et al., 2020; SEDREZ-PORTO JA, et al., 2017; SEDREZ-PORTO et al., 2016; TUNCER S, et al., 2013).

On the other hand, it was not verified in the literature the presence of any systematic review that evaluated whether the presence of modeling agents in the restoration affects the final properties of the material. Therefore, the aim of this systematic review was to evaluate the influence of the use of modeling agents for composite resins, both the modeling liquid and the adhesive, during the restoration on the properties of color change (∆E), microhardness and roughness surface of this material.

The null hypothesis established for this study was that the use of modeling agents for composite resin during the realization of the incremental technique does not interfere in the properties of color change, microhardness and surface roughness of the material.

METHODS

Registration protocol

This systematic review is reported according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) checklist. This systematic review was recorded in the International Prospective Register of Systematic Reviews (PROSPERO) under the number CRD42021238167.

Eligibility Criteria

The conducted question of the study was "Does the use of composite resin modeling agents during the incremental technique change the material properties?" based on PICO criteria. In view of this, Population (P) consisted of composite resins manipulated by the incremental technique; Intervention (I) was the use of modeling agents, either modeling liquid and adhesive system during restoration; Comparison (C) was the manipulation of composite resin without modeling agent and Outcomes (O) evaluated were color change (ΔE) as primary outcome, surface microhardness and roughness as secondary outcome. The inclusion criteria were studies published in English, in vitro studies published between 2000 and 2021 that evaluated at least the color properties of composite resins manipulated with some modeling agent, either a modeling liquid or an adhesive system. The exclusion criteria were animal studies, retrospective studies, literature reviews, studies without a control group, studies that used modeling agents but did not assess established outcomes.

Information Sources and Search strategy

The electronic literature search was performed by two researchers working independently (A.R.J.S. and R.I.S.G.). Studies were selected and included/excluded based on the title and abstract in the PubMed/MEDLINE, Scopus and Web of Science databases. The search strategy is shown in table 1. To complement this review, the same researchers conducted a manual search. This search was conducted in January 2022, with a limited year of publication between 2000 and 2021. The studies were previously selected and classified according to eligibility criteria by reading the title and abstract, but those for which inclusion or exclusion was not clear were read in full so that the decision could be made.

Data analysis

One of the authors (A.R.J.S.) collected important information from the articles and a second author (R.I.S.G.) reviewed all the information collected. A careful analysis was performed to verify disagreements between the authors and, if there was any, a consensus was reached between the two authors.

Risk of bias

The two researchers (A.R.J.S. and R.I.S.G.) evaluated the methodological quality of the studies according to a previous study (ASTUDILLO-RUBIO D, et al., 2018) and five parameters were evaluated: 1. Standardization of sampling procedures, 2. Single operator for execution of the protocol, 3. Description of sample size calculation, 4. Blinding of test operator, 5. Calibration of operator before testing. If the article clearly reported the evaluated parameter, it received a score of 0, if the parameter was insufficiently or uncertainly reported, the score was 1, when it was not possible to find the information on the evaluated parameter, the score was 2. Therefore, the articles with scores total between 0 and 3 were classified as low risk of bias, those with scores from 4 to 7 as moderate risk and scores from 8 to 10 as high risk.

Quantitative analysis

The meta-analysis (Reviewer Manager 5.4 software, The Cochrane Collaboration, Copenhagen, Denmark) was based on the Mantel-Haenzel (MH) and Inverse Variance (IV) methods. The data from the included studies were continuous (composite resin color change) comparing the use of Adper™ Scotchbond™ Multi-Purpose Adhesive (3M ESPE, St. Paul, MN, USA) as a modeling agent with the control group. These data were evaluated using Differences of Means (DMs), with a Confidence Interval (CI) of 95%. Values were considered significant when $p < 0.05$.

Additional analysis

The Kappa score test was used to calculate the level of concordance between authors during the selection process of the articles in the PubMed/MEDLINE, Scopus and Web of Science databases. Any disagreements were resolved by discussion until consensus was reached among the authors.

Table 1 - Search strategy.

PUBMED/MEDLINE	
1 - AND 2 AND - 3	
1	((((((((Composite Resins) OR (Composite Resin)) OR (Resin, Composite)) OR (Resins, Composite)) OR (Resins, Synthetic)) OR (Dental Resins)) OR (Dental Resin)) OR (Resin, Dental)) OR (Resins, Dental).
2	(((((Modeling liquid Resin) OR (Modeler liquid)) OR (Modeling liquid)) OR (Modeling resin)) OR (Modeling agents)) OR (Modeling liquids).
3	((((((((((((((((((Materials Testing) OR (Testing, Materials)) OR (Surface Properties)) OR (Properties, Surface)) OR (Property, Surface)) OR (Surface Property)) OR (Mechanical Tests)) OR (Mechanical Test)) OR (Test, Mechanical)) OR (Tests, Mechanical)) OR (Mechanical Testing)) OR (Testing, Mechanical)) OR (Hardness Tests)) OR (Hardness Test)) OR (Test, Hardness)) OR (Tests, Hardness)) OR (Color)) OR (Colors)) OR (Roughness).
1 - AND 2 AND - 3	
SCOPUS	
1	(TITLE-ABS-KEY ("Composite Resins") OR TITLE-ABS-KEY ("Composite Resin") OR TITLE-ABS-KEY ("Resin, Composite") OR TITLE-ABS-KEY ("Resins, Composite") OR TITLE-ABS-KEY ("Resins, Synthetic") OR TITLE-ABS-KEY ("Dental Resins") OR TITLE-ABS-KEY ("Dental Resin") OR TITLE-ABS-KEY ("Resin, Dental") OR TITLE-ABS-KEY ("Resins, Dental").
2	(TITLE-ABS-KEY (“Modeling liquid Resin") OR TITLE-ABS-KEY ("Modeler liquid") OR TITLE-ABS-KEY ("Modeling liquid") OR TITLE-ABS-KEY ("Modeling resin") OR TITLE-ABS-KEY ("Modeling agents") OR TITLE-ABS-KEY ("Modeling liquids").
3	(TITLE-ABS-KEY ("Materials Testing") OR TITLE-ABS-KEY ("Testing, Materials") OR TITLE-ABS-KEY ("Surface Properties") OR TITLE-ABS-KEY ("Properties, Surface") OR TITLE-ABS-KEY ("Property, Surface") OR TITLE-ABS-KEY ("Surface Property") OR TITLE-ABS-KEY ("Mechanical Tests") OR TITLE-ABS-KEY ("Mechanical Test") OR TITLE-ABS-KEY ("Test, Mechanical") OR TITLE-ABS-KEY ("Tests, Mechanical") OR TITLE-ABS-KEY ("Mechanical Testing") OR TITLE-ABS-KEY ("Testing, Mechanical") OR TITLE-ABS-KEY ("Hardness Tests") OR TITLE-ABS-KEY ("Hardness Test") OR TITLE-ABS-KEY ("Test, Hardness") OR TITLE-ABS-KEY ("Tests, Hardness") OR TITLE-ABS-KEY ("Color") OR TITLE-ABS-KEY ("Colors") OR TITLE-ABS-KEY ("Roughness").
1 - AND 2 AND - 3	
WEB OF SCIENCE	
1	TS= (Composite Resins OR Composite Resin OR Resin, Composite OR Resins, Composite OR Resins, Synthetic OR Dental Resins OR Dental Resin OR Resin, Dental OR Resins, Dental)
2	TS= (Modeling liquid Resin OR Modeler liquid OR Modeling liquid OR Modeling resin OR Modeling agents OR Modeling liquids)
3	TS= (Materials Testing OR Testing, Materials OR Surface Properties OR Properties, Surface OR Property, Surface OR Surface Property OR Mechanical Tests OR Mechanical Test OR Test, Mechanical OR Tests, Mechanical OR Mechanical Testing OR Testing, Mechanical OR Hardness Tests OR Hardness Test OR Test, Hardness OR Tests, Hardness OR Color OR Colors OR Roughness).

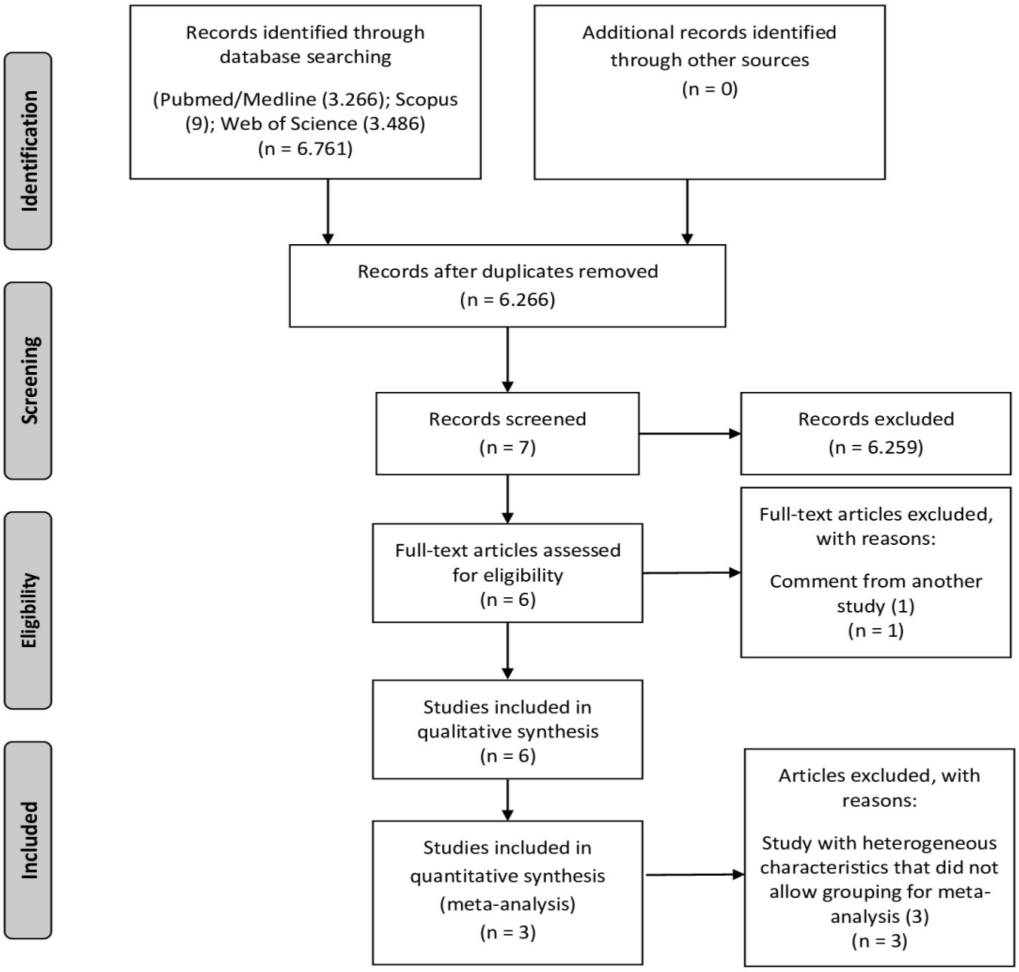
Source: Silva ARJ, et al., 2024.

RESULTS

Literature search

The initial electronic search provided 6,761 articles: 3,266 from Pubmed/Medline, 9 from Scopus, and 3,486 from Web of Science. After removing duplicates, 6,266 articles were obtained for reading the title and abstract and the eligibility criteria were applied, resulting in seven studies (ARAUJO FS, et al., 2018; MÜNCHOW EA, et al., 2016; KUTUK ZB, et al., 2020; SEDREZ-PORTO JA, et al., 2017; SEDREZ-PORTO et al., 2016; TUNCER S, et al., 2013; KIMMES NS, et al., 2013) for analysis. After the complete reading of these articles, one was excluded because it was a comment from another study (KIMMES NS, et al., 2013). Therefore, six articles were included in this systematic review (ARAUJO FS, et al., 2018; MÜNCHOW EA, et al., 2016; KUTUK ZB, et al., 2020; SEDREZ-PORTO JA, et al., 2017; SEDREZ-PORTO et al., 2016; TUNCER S, et al., 2013). The details of the search strategy are described in the form of a flowchart in (**Figure 1**). The values obtained by the Kappa test for the databases were: Pubmed/Medline (1.0), Scopus (0.8) and Web of Science (1.0), suggesting a high level of agreement between the authors.

Figure 1 - Flowchart describing the electronic search and selection of studies.



Source: Silva ARJ, et al., 2024.

Characteristics of the included studies

The characteristics of each study, including all the information collected are described in tables 2 and 3. The composite resins tested in the evaluated studies were: 4 nano-hybrid, 4 nanoparticulate, 3 micro-hybrid and 1 hybrid. The samples varied between discs and cylinders, with some differences in diameter and thickness between them, having been stored in distilled water, coffee solution, grape juice and red wine. The modeling agents used were two modeling liquids and five different adhesive systems. The measurement of the color change of composite resins in all studies was performed using a spectrophotometer, as well as the microhardness was evaluated using the Vickers technique in kg/mm² and the surface roughness measured with a profilometer in the studies that evaluated these variables.

Assessment of the risk of bias

The analysis of the included studies regarding the risk of bias is described in **Table 4**. It was observed that for parameter 1, which concerns the standardization of sampling procedures, all studies clearly reported that there was standardization, and thus received a score of 0. For the other four parameters, all studies did not report the necessary information and received score 2, with the exception of one (ARAUJO FS, et al., 2018) that in parameter 3 (sample calculation) reported clearly and received a score of 0. Thus, five studies (MÜNCHOW EA, et al., 2016; KUTUK ZB, et al., 2020; SEDREZ-PORTO JA, et al., 2017; SEDREZ-PORTO et al., 2016; TUNCER S, et al., 2013) were classified as high risk of bias, while only one (ARAUJO FS, et al., 2018) presented moderate risk of bias.

Table 2 - Characteristics of included studies (part 1).

Author	Type of study	Tested composite resin	Follow-up time	Characteristics of sample	Modeling agent(s) used in the experimental group	Composition of the modeling agent(s) used
Kutuk et al., 2020.	In vitro.	Nano-hybrid. Essentia Dark Enamel (GC Corp., Tokyo, Japan).	6 weeks.	Cylinder with 12mm diameter and 2mm thickness.	EG1: UDMA, 2-hydroxy-1,3 dimethacryloxy propane, 2-hydroxyethyl methacrylate; EG2: 10-methacryloyloxydecyl dihydrogen phosphate, 4-methacryloxyethyl trimellitate, methacryloyloxyalkyl thiophosphate methylmethacrylate, methacrylate monomer, acetone, water, silica, initiator; EG3: Glycerol phosphate dimethacrylate, hydrophilic co-monomers, water, ethanol, acetone.	EG1: UDMA, 2-hydroxy-1,3 dimethacryloxy propane, 2-hydroxyethyl methacrylate; EG2: 10-methacryloyloxydecyl dihydrogen phosphate, 4-methacryloxyethyl trimellitate, methacryloyloxyalkyl thiophosphate methylmethacrylate, methacrylate monomer, acetone, water, silica, initiator; EG3: Glycerol phosphate dimethacrylate, hydrophilic co-monomers, water, ethanol, acetone.
Araújo et al., 2018.	In vitro.	Nano-hybrid; Filtek Z-250 A3 (3M ESPE, St. Paul, MN, USA).	200 termocycles.	Cylinder with 10mm diameter and 1,5mm thickness	EG1: Adhesive 1- Adper Universal; EG2: Adhesive 2- Adper Scotchbond Multipurpose.	Not available
Sedrez-Porto et al., 2017.	In vitro.	Nanoparticulate; Filtek Z350 XT (3M ESPE, St. Paul, MN, USA).	12 months.	Disc with 6mm diameter and 2mm thickness.	EG1: The Bond componentof Adper Scotchbond Multi-Purpose Adhesive (3M ESPE, St. Paul, MN, USA); EG2: Adper Single Bond 2 Adhesive (3M ESPE, St. Paul, MN, USA)	Not available
Sedrez-Porto et al., 2016.	In vitro.	Nanoparticulate; Filtek Z350 XT (3M ESPE, St. Paul, MN, USA).	12 months.	Disc with 6mm diameter and 2mm thickness.	Scotchbond multi-Purpose Adhesive, SBMP (3M ESPE, St. Paul, MN, USA).	Not available
Münchow et al., 2016.	In vitro	Nanoparticulate; Filtek Z350 XT (3M ESPE, St. Paul, MN, USA).	6 months	Disc with 6mm diameter and 2mm thickness.	EG1: The Bond componentof Adper Scotchbond Multi-Purpose Adhesive (3M ESPE, St. Paul, MN, USA); EG2: Adper Single Bond 2 Adhesive (3M ESPE, St. Paul, MN, USA).	Not available

Author	Type of study	Tested composite resin	Follow-up time	Characteristics of sample	Modeling agent(s) used in the experimental group	Composition of the modeling agent(s) used
Tuncer et al., 2013.	In vitro.	Nano-hybrid; GrandioSO (Voco, Cuxhaven, Germany); Micro-hybrid; Gradia Direct Posterior (GC America, Alsip, IL, USA); Hybrid; Aelite LS Posterior (Bisco, Schaumburg, IL, USA); Micro-hybrid; Filtek Silorane (3M ESPE, St. Paul, MN USA); Micro-hybrid; Aelite All Purpose Body (Bisco, Schaumburg, IL, USA); Nanoparticulate Filtek Ultimate (3M ESPE, St. Paul, MN, USA); Nano-hybrid; Clearfil Majesty Esthetic (Kuraray Medical Inc., Tokyo, Japan.	10.000 termocycles.	Disc with 8mm diameter and 2mm thickness.	Modeling Resin (Bisco, Schaumburg, IL, USA).	UDMA, ethoxylated Bis-GMA and Amorphous sílica.

Note: Abbreviations: EG, Experimental Group; UDMA, Urethane Dimethacrylate.

Source: Silva ARJ, et al., 2024.

Table 3 – Characterisctis of incluided studies.

Author	Samples (N)	Evaluation method of material properties	Storage media of samples	Evaluation moments	Means of color change (±Standart deviation)	
					Experimental group	**Control group**
Kutuk et al., 2020.	64	Color change (CIE L*, a*, b*, and ΔE*) measured with spectrophotometer (VITA Easy Shade; Vident, Brea, CA, USA), + Vickers Microhardness (VHN) in kg/mm² (Shimadzu HMV/2000, Shimadzu Corporation, Kyoto, Japan), + Surface roughness measured with profilometerer (Perthometer M2, Mahr, Göttingen, Germany).	Distilled water.	Baseline	NA	NA
				1 week	Not available	Not available
				6 weeks	Not available	Not available
			Coffee solution (7,5g of coffee + 500mL ofboiling water).	Baseline	NA	NA
				1 week	Not available	Not available
				6 weeks	Not available	Not available
Araújo et al., 2018.	30	Color change (CIE L*, a*, b*, and ΔE*) measured with spherical spectrophotometer (SP60, X-Rite, Grand Rapids, MI, USA).	Water at 37°C **or** Grape juice at 5°C (Tang®, Curitiba, PR, Brazil) (25g of powder + 1L of cold filtered water) **or** Coffee at 55°C (Pilão®, São Paulo, SP, Brazil) (3,4g of coffee powder in 300 mL of boiled filtered water).	Baseline	NA	NA
				After 200 thermocycles	EG1: 3.44 (±0.95) EG2: 6.97 (±3.25)	6.63 (±1.52)
Sedrez-Porto et al., 2017.	30	Color change (CIE L*, a*, b*, and ΔE*) measured with spectrophotometer (VITA Easy Shade; Vita Zahnfabrik, Bad Sackingen, Alemanha).	Distilled water (pH 5,9).	Baseline	NA	NA
				6 months	EG1: 3.1 (±0.8) EG2: 3.1 (±0.6)	2.0 (±0.2)
				12 months	EG1: 3.1 (±0.8 EG2: 3.7 (±0.7)	3.4 (±0.3)
			Red wine (Cabernet Sauvignon 2007, Concha y Toro, Las Condes, Chile – pH 3.6 and 14.5 vol.% alcohol)	Baseline	NA	NA
				6 months	EG1: 13.2 (±2.0) EG2: 20.6 (±5.4)	20.2 (±1.3)
				12 months	EG1: 14.8 (±2.5) EG2: 18.6 (±3.6)	23.4 (±2.9)
Sedrez-Porto et al., 2016.	28	Color change (CIE L*, a*, b*, and ΔE*) measured with spectrophotometer (VITA Easy Shade; Vita Zahnfabrik, Bad Sackingen, Alemanha).	Red wine (Cabernet Sauvignon 2007, concha y Toro, Las Condes, Chile – pH 3.6 and 14.5 vol.% alcohol)	Baseline	NA	NA
				4 months	23.0 (±3.2)	22.0 (±3.4)
				6 months	13.9 (±2.6)	21.1 (±2.6)
				12 months	15.6 (±3.1)	24.1 (±3.1)

Author	Samples (N)	Evaluation method of material properties	Storage media of samples	Evaluation moments	Means of color change (±Standart deviation)	
					Experimental group	Control group
Münchow et al., 2016.	28 60	Color change (CIE L*, a*, b*, and ΔE*) measured with spectrophotometer (VITA Easy Shade; Vita Zahnfabrik, Bad Sackingen, Alemanha).	Distilled water (pH 5,9)	Baseline	NA	NA
				24h	EG1: 1.2 (±0.4) EG2: 1.7 (±0.6)	0.5 (±0.2)
				7 days	EG1: 1.1 (±0.3) EG2: 2.1 (±0.7)	1.3 (±1.0)
				3 months	EG1: 2.1 (±1.0) EG2: 1.8 (±0.7)	2.5 (±1.0)
				6 months	EG1: 4.0 (±2.0) EG2: 3.3 (±0.6)	2.8 (±1.0)
Münchow et al., 2016.		Color change (CIE L*, a*, b*, and ΔE*) measured with spectrophotometer VITA Easyshade Compact (VITA Zahnfabrik, Bad Sackingen, Germany, Model DEASYCHP) + Vickers Microhardness (VHN) in kg/mm²(Shimadzu HMV/2000, Shimadzu Corporation, Kyoto, Japan) + Surface roughness measured with profilometerer (Surtronic 3+, Taylor Hobson, Leicester, UK).	Red wine (Cabernet Sauvignon 2007, Concha y Toro, Las Condes, Chile – pH 3.6 and 14.5 vol.% alcohol)	Baseline	NA	NA
				24h	EG1: 5.1 (±2.0) EG2: 5.0 (±1.2)	7.4 (±2.1)
				7 days	EG1: 9.6 (±3.3) EG2: 10.9 (±2.4)	13.0 (±2.8)
				3 months	EG1: 15.8 (±4.9) EG2: 22.1 (±6.7)	19.5 (±5.0)
				Baseline	NA	NA
			Distilled water.	After 10.000 thermocycles	1.62 (±0.34) 1.64 (±0.36) 1.52 (±0.28) 2.53 (±0.45) 1.79 (±0.19) 1.10 (±0.26) 2.2 (±0.23)	1.49 (±0.31) 1.68 (±0.38) 1.96 (±0.16) 1.79 (±0.18) 2.17 (±0.4) 1.28 (±0.19) 2.34 (±0.35)
				6 months	EG1: 13.5 (±5.6) EG2: 20.4 (±4.3)	20.1 (±5.9)
				6 months	EG1: 13.5 (±5.6) EG2: 20.4 (±4.3)	20.1 (±5.9)

Source: Silva ARJ, et al., 2024.

Main findings

For the primary outcome of color change (ΔE) of composite resin, studies showed that the use of modeling agents during the manipulation and insertion of the restorative composite by the incremental technique protects against color change and reduces the susceptibility of staining of the composite resin by coloring substances, such as those used to store the samples in the studies: coffee solution, grape juice and red wine. Some studies showed that this ability to protect against changes in color parameters promoted by the modeling agent was more evident in the first six months of storage, that is, only after this period of time were the changes more relevant, but still significantly smaller than the than those that occurred in the control group.

Another characteristic that was identified as relevant for the choice of modeling agents is their composition, as it has been reported that hydrophilic materials seem to have a more negative impact on the color stability of composites. Therefore, the ideal modeling agent must have a hydrophobic composition to be positive on the composite resin properties.

The two studies (KUTUK ZB, et al., 2020; TUNCER S, et al., 2013) that evaluated microhardness and surface roughness observed that the influence of modeling agents on these properties varies according to the composite used. Furthermore, no significant positive differences were observed for the use of these agents compared to the control group, except when the primer of a self-adhesive system was used, as this negatively influenced both properties of the composite resin, this finding being justified by the composition of the liquid to be hydrophilic.

Table 4 - Detailed evaluation of studies regarding the risk of bias.

Domain	Kutuk et al., 2020	Araújo et al., 2018	Sedrez-porto et al., 2017	Sedrez-porto et al., 2016	Munchow et al., 2016	Tuncer et al., 2013
1. Standardization of sampling procedures	0	0	0	0	0	0
2. Single operator for execution of the protocol	2	2	2	2	2	2
3. Description of sample size calculation	2	0	2	2	2	2
4. Blinding of test operator	2	2	2	2	2	2
5. Calibration of operator before testing	2	2	2	2	2	2
Total score	8	6	8	8	8	8
General risk of bias	High risk of bias	Moderate risk of bias	High risk of bias	High risk of bias	High risk of bias	High risk of bias

Source: Silva ARJ, et al., 2024.

Meta-analysis

Primary outcome: Color change of composite resin

When analyzing all the included studies, only three (MÜNCHOW EA, et al., 2016; SEDREZ-PORTO JA, et al., 2017; SEDREZ-PORTO et al., 2016) presented similar characteristics and sufficient homogeneity for the grouping in the meta-analysis, which evaluated the color change of composite resin stored in red wine for 6 months and for 12 months comparing the use of Adper™ Scotchbond™ Multi-Purpose Adhesive (3M ESPE, St. Paul, MN, USA) as a modeling agent with the control group.

Six months of storage

Three studies (MÜNCHOW EA, et al., 2016; SEDREZ-PORTO JA, et al., 2017; SEDREZ-PORTO et al., 2016) evaluated the color change of composite resin after six months of immersion in red wine (**Figure 2**). The results showed statistically significant differences between the two groups, favoring the experimental group ($p = 0.00001$; Mean Difference: -7.04; CI: -8.64 to -5.44). Data did not show heterogeneity ($Chi^2 = 0.04$; I^2: 0%; $p = 0.98$).

Twelve months of storage

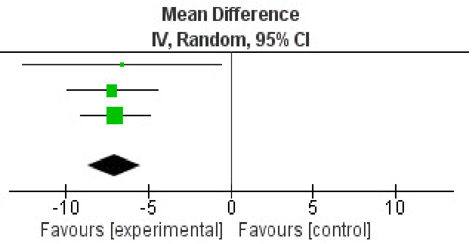
Two studies (SEDREZ-PORTO JA, et al., 2017; SEDREZ-PORTO et al., 2016) evaluated the change in color of the composite resin after twelve months of immersion in red wine (Figure 2). There were significant differences between the experimental group and the control group, again favoring the experimental group (p = 0.00001; Mean Difference: -8.55; CI: -10.88 to -6.21). Furthermore, heterogeneity was not significant (Chi^2 = 0.00; I^2: 0%; p = 0.97).

Figure 2 - Forest plots forcolor change of composite resin.

Six months of storage

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Münchow et al., 2016	13.5	5.6	7	20.1	5.9	7	7.0%	-6.60 [-12.63, -0.57]
Sedrez-Porto et al., 2016	13.9	2.6	7	21.1	2.6	7	34.5%	-7.20 [-9.92, -4.48]
Sedrez-Porto et al., 2017	13.2	2	5	20.2	1.3	5	58.5%	-7.00 [-9.09, -4.91]
Total (95% CI)			**19**			**19**	**100.0%**	**-7.04 [-8.64, -5.44]**

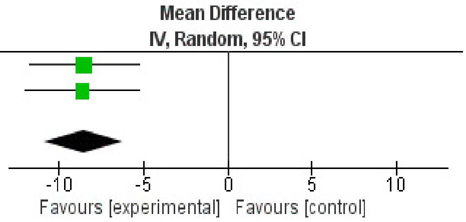
Heterogeneity: Tau² = 0.00; Chi² = 0.04, df = 2 (P = 0.98); I² = 0%
Test for overall effect: Z = 8.63 (P < 0.00001)



Twelve months of storage

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Sedrez-Porto et al., 2016	15.6	3.1	7	24.1	3.1	7	51.6%	-8.50 [-11.75, -5.25]
Sedrez-Porto et al., 2017	14.8	2.5	5	23.4	2.9	5	48.4%	-8.60 [-11.96, -5.24]
Total (95% CI)			**12**			**12**	**100.0%**	**-8.55 [-10.88, -6.21]**

Heterogeneity: Tau² = 0.00; Chi² = 0.00, df = 1 (P = 0.97); I² = 0%
Test for overall effect: Z = 7.18 (P < 0.00001)



Source: Silva ARJ, et al., 2024.

DISCUSSION

The results of this review presented that the color change characteristics (ΔE) of the evaluated composite resins were positively affected by the use of modeling agents, so that they performed a protective function against color change and reduction of resin staining by coloring substances up to 12 months of storage, but only in cases where modeling liquid or universal adhesive with hydrophobic characteristics was used. As for microhardness and surface roughness, no great differences were observed in the use of modeling agents when compared to the control group. Thus, the established null hypothesis was partially rejected.

The color change in composite resins can be influenced by intrinsic and extrinsic factors, since both the chemical composition, especially the type of organic matrix, filler particles and photoinitiators, and the interaction of the material with coloring substances are related to this change (SAMRA AP, et al., 2008; SARAFIANOU A, et al., 2007; BARUTCIGIL Ç e YILDIZ M, 2012). Still regarding these color changes in the composite resin, it has been verified that this process is time-dependent, so in vitro studies with follow-up of up to four months may be insufficient to detect significant differences between two distinct groups (SEDREZ-PORTO et al., 2016). This helps to justify the choice for inclusion in the meta-analysis only for studies with follow-up of at least six months. On the other hand, the mechanical fatigue of composite resins is mainly related to two zones: the organic phase and the matrix/filler particle interface (LOHBAUER U, et al., 2013).

According to the hydrophilicity of the material, water absorption may have bigger or smaller intensity (MUNCHOW EA, et al., 2014; SIDERIDOU ID, et al., 2011). Therefore, materials with hydrophilic monomers and solvents become physically unstable and, therefore, if used as a modeling agent for composite resin, they end up damage its properties, due to its high sorption of water and dyes (MÜNCHOW EA, et al., 2016).

Specifically talking about the color change (ΔE) results evaluated in the meta-analysis, red wine was used as a coloring substance in all included studies (MÜNCHOW EA, et al., 2016; SEDREZ-PORTO JA, et al., 2017; SEDREZ-PORTO et al., 2016), being a highly potent coloring substance with a low pH, which causes more significant changes in composite resin samples when compared to distilled water (SEDREZ-PORTO JA, et al., 2017).

The Adper™ Scotchbond™ Multi-Purpose adhesive controlled the color change of the samples made with it when compared to the control group, which did not receive any modeling agent, in the meta-analysis of six months and twelve months of storage. This fact can be explained by the creation of a protective barrier against the coloring substance, reducing the chance of the composite go thru hydrolysis (KARABELA MM e SIDERIDOU ID, 2008) preventing the rapid degradation and discoloration of the material (SEDREZ-PORTO JA, et al., 2017) through the formation of stable intermolecular chains with the monomers of the composite resin, all of which is capable of reducing the penetration of wine coloring molecules into the internal structure of the material (SEDREZ-PORTO et al., 2016).

One study associated the presence of hydrophilic monomers, water and ethanol in a primer of a two-step self-etching system tested as a modeling agent with a reduction in the microhardness of the composite resin by having attracted additional water to the resin matrix, in addition to having probably increased the color change (KUTUK ZB, et al., 2020). Therefore, in the meta-analysis, the Adper™ Scotchbond™ Multi-Purpose adhesive played a positive role in protecting the composite resin against color change when used as a modeling agent, due to its hydrophobic composition (KARABELA MM e SIDERIDOU ID, 2008).

The results obtained in the present study confirm the relevance of the tested universal adhesive, as well as the modeling liquid as modeling agents capable of preventing irregularities and defects in composite resin restorations, as verified in a recent study (KUTUK ZB, et al., 2020). This may be related to the ability of these modeling agents to improve the adaptation of the composite increments, in addition to preventing it from adhering to manual instruments (KUTUK ZB, et al., 2020). Therefore, knowing that the optical properties of composites do not remain stable over time due to the degradation they can experience in the oral environment (PRODAN DA, et al., 2015) and that a minimum ΔE is desirable for all restorations with composite resin, but especially when involving anterior teeth (MÜNCHOW EA, et al., 2016; SEDREZ-PORTO JA, et al., 2017), choosing a modeling agent that plays an important role in color stability is essential.

As the main limitation of this study, the high risk of bias found in most of the included studies should be mentioned, which makes it difficult to extrapolate with a certain level of confidence the results obtained for clinical practice. Therefore, it is recommended that new laboratory tests be performed with standardization of all criteria used in the assessment of the methodological quality of the studies, so that new information on the properties of restorations performed with modeling agents can be generated with a high level of confidence.

FINAL CONSIDERATIONS

This systematic review and meta-analysis demonstrated that the use of modeling liquid and universal adhesive with hydrophobic composition as modeling agents of composite resin helps to maintain the color stability of the restoration, providing higher resistance to pigmentation with low color change (ΔE) of the composite, even after 12 months of storage in red wine, thanks to its hydrophobicity. The microhardness and surface roughness properties were not affected, neither positively nor negatively, by the use of these modeling agents. However, it is important to pay attention that it is necessary to be cautious in evaluating these results due to the high risk of bias found in most of the studies included in this work.

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