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SYSTEMATIC REVIEW ARTICLE

Effect of glycerin application on the surface hardness of composite resins: A systematic review of in vitro studies

Efecto de la Aplicación de Glicerina en la Dureza Superficial de las Resinas Compuestas: Revisión Sistemática de Estudios In Vitro

Alain Manuel Chaple Gil[1*], Lazareth Liz Ortiz Santiago[2], Laura Pereda Vázquez[2], Meylin Santiesteban Velázquez[3]

[1]Universidad Autónoma de Chile, Facultad de Ciencias de la Salud. Santiago de Chile, Chile.
[2]Private Practice. Florida, United States of America.
[3]Universidad de Ciencias Médicas de La Habana. Facultad de Ciencias Médicas "Victoria de Girón". La Habana, Cuba.

***Corresponding Author:** alain.chaple@uautonoma.cl

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ABSTRACT

Introduction: The application of glycerin to dental composite resins before curing has been widely discussed in academic and clinical settings, often without empirical validation.

Objective: This systematic review aimed to evaluate whether glycerin application prior to light-curing improves the surface hardness of composite resins, synthesizing evidence from in vitro studies.

Material and Methods: A comprehensive search was conducted across PubMed, Scopus, Web of Science, and Cochrane Library, following PRISMA guidelines and a registered PROSPERO protocol. Eligible studies included in vitro research comparing surface hardness outcomes between glycerin-treated and untreated composite resin groups. Risk of bias was assessed using the RoBDEMAT tool, and data were narratively synthesized due to methodological heterogeneity.

Results: Three studies met the inclusion criteria. All reported a consistent increase in surface hardness following glycerin application, attributed to its ability to minimize the oxygen-inhibited layer and enhance polymerization. Notably, medical-grade glycerin demonstrated superior performance compared to dental formulations. However, exposure to acidic environments post-curing was found to reduce this benefit. Risk of bias analysis revealed moderate concerns, particularly due to unreported randomization and operator blinding procedures.

Conclusions: In conclusion, in vitro evidence supports the beneficial role of glycerin in enhancing the surface hardness of composite resins when applied before curing. These findings reinforce glycerin's utility as a clinically relevant adjunct in restorative dentistry. Nonetheless, the lack of clinical studies and standardization in glycerin formulation highlights the need for further high-quality research under simulated oral conditions to establish definitive clinical guidelines.

Keywords:

Composite Resins; Glycerol; Surface Properties; Hardness; Polymerization; In Vitro Techniques; Evidence-Based Dentistry.

RESUMEN

Introducción: La aplicación de glicerina en resinas compuestas dentales antes de la fotopolimerización ha sido ampliamente debatida en ámbitos académicos y clínicos, a menudo sin validación empírica.

Objetivo: Esta revisión sistemática tuvo como objetivo evaluar si la aplicación de glicerina antes de la fotocurado mejora la dureza superficial de las resinas compuestas, sintetizando la evidencia disponible en estudios in vitro.

Material y Métodos: Se realizó una búsqueda exhaustiva en PubMed, Scopus, Web of Science y Cochrane Library, siguiendo las directrices PRISMA y un protocolo registrado en PROSPERO. Se incluyeron estudios in vitro que compararan la dureza superficial entre grupos con y sin aplicación de glicerina. El riesgo de sesgo se evaluó mediante la herramienta RoBDEMAT, y los datos se sintetizaron de forma narrativa debido a la heterogeneidad metodológica.

Resultados: Tres estudios cumplieron con los criterios de inclusión. Todos reportaron un aumento consistente en la dureza superficial tras la aplicación de glicerina, atribuido a su capacidad para minimizar la capa inhibida por oxígeno y mejorar la polimerización. Cabe destacar que la glicerina de grado médico mostró un rendimiento superior frente a las formulaciones dentales. Sin embargo, la exposición a medios ácidos tras la fotopolimerización redujo este beneficio. El análisis del riesgo de sesgo evidenció preocupaciones moderadas, particularmente por la falta de información sobre aleatorización y cegamiento del operador.

Conclusiones: En conclusión, la evidencia in vitro respalda el papel beneficioso de la glicerina para aumentar la dureza superficial de las resinas compuestas cuando se aplica antes del curado. Estos hallazgos refuerzan su utilidad clínica como coadyuvante en odontología restauradora. No obstante, la ausencia de estudios clínicos y la falta de estandarización en la formulación de la glicerina subrayan la necesidad de investigaciones de alta calidad en condiciones orales simuladas para establecer guías clínicas definitivas.

Palabras Claves:

Resinas Compuestas; Glicerol; Propiedades Superficiales; Dureza; Polimerización; Técnicas In Vitro; Odontología Basada en la Evidencia.

INTRODUCTION

The application of glycerin to composite resins was shown to positively influence their surface hardness. This effect was primarily attributed to glycerin's ability to enhance the polymerization process by minimizing the formation of the oxygen-inhibited layer (OIL), which would otherwise compromise the surface hardness of the material. The reviewed studies provided evidence supporting the beneficial role of glycerin in preserving or improving the surface hardness of composite resins under various conditions.[1]

The application of glycerin prior to light-curing significantly increased the surface hardness of nanohybrid composite resins, even after immersion in alcoholic mouthwash. This effect was attributed to glycerin's contribution to a more effective polymerization process, as evidenced by the significant difference in hardness between treated and untreated samples ($p < 0.005$).[2] In the case of nanofilled composites, the highest hardness values were observed in specimens treated with glycerin, particularly when no acidic conditions such as immersion in apple cider vinegar were applied.[3] A similar effect was observed in microhybrid composites, where glycerin enhanced compressive strength by limiting OIL formation, even when the materials were exposed to acidic solutions such as black coffee.[4]

Both Mylar strip coverage and glycerin application led to improved surface hardness immediately after curing, with glycerin-treated samples exhibiting greater hardness compared to those exposed to air alone. Polishing after curing was identified as the most effective method for enhancing surface hardness, suggesting that while glycerin application was beneficial, it could be further complemented by post-curing treatments.[1]

Despite growing interest in the effect of glycerin application on the surface hardness of composite resins, a considerable number of unverified claims, personal opinions, and clinically oriented suggestions were found to circulate within academic settings and social media platforms. These assertions often lacked empirical support and were not grounded in evidence obtained through systematic scientific inquiry. The widespread dissemination of such speculative content highlighted a significant gap between clinical practice and research-based evidence.

This situation raised concerns regarding the reliability of the information being shared and underscored the importance of identifying whether these widely held beliefs were substantiated by high-quality scientific studies. Therefore, it was deemed necessary to investigate the extent to which published research in peer-reviewed journals, indexed in reputable databases such as PubMed, Scopus, and Web of Science, had addressed this issue using methodologically rigorous approaches.

Accordingly, this study was designed to critically examine the existing scientific literature both clinical and in vitro regarding the effect of glycerin application on the surface hardness of composite resins. The aim was to determine whether the observed assumptions were supported by valid experimental findings and to provide an evidence- based foundation for clinical decision-making.

Research question: What is the effect of glycerin application prior to light curing on the surface hardness of dental composite resins?

The **objective** of this research is to systematically evaluate the effect of glycerin application prior to light-curing on the surface hardness of composite resins, based on evidence from in vitro studies.

MATERIALS AND METHODS

A systematic review was conducted to investigate the effect of glycerin applications prior to light curing on the surface hardness of dental composite resins. The review adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[5] This systematic review protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) under the registration ID CRD420251074130.

Eligibility Criteria

Studies were eligible for inclusion if they met the following criteria: (Population) *in vitro* studies evaluating the surface hardness of dental composite resins; (Intervention) inclusion of at least one group in which glycerin was applied prior to photoactivation; (Control) inclusion of a control group without glycerin application; (Outcome) measurement of surface hardness using standardized methods; and full-text availability. Studies were excluded if they evaluated materials other than composite resins, did not include a comparison group, lacked surface hardness data, or were review articles, case reports, editorials, or conference abstracts.

Information Sources and Search Strategy

A comprehensive search was performed in five electronic databases: PubMed, Scopus, Web of Science (WoS), and Cochrane Library. Searches were conducted between march and may using predefined strategies combining terms related to composite resins and glycerin. The search terms were adapted to each database's specific syntax. (Table 1)

Table 1: Search queries

Database	Formulation	Filters
Pubmed	(("Composite Resins"[Mesh] OR "resin composite"[Title/Abstract] OR "composite resin"[Title/Abstract]) AND ("Glycerol"[Mesh] OR glycerin[Title/Abstract] OR glycerol[Title/Abstract]))	NA*
Scopus	TITLE-ABS-KEY(("resin composite" OR "composite resin" OR "composite resins") AND (glycerin OR glycerol))	AND (LIMIT-TO (DOCTYPE , "ar"))
WoS	TS=(("resin composite" OR "composite resin" OR "composite resins") AND (glycerin OR glycerol))	Refined By: Document Types: Article
Cochrane Library	("resin composite":ti,ab,kw OR "composite resin":ti,ab,kw) AND (glycerin:ti,ab,kw OR glycerol:ti,ab,kw)	Limited to "Trials"

**NA = Not Applicable.*

The most recent search across all databases was conducted on May 13, 2025. Additionally, alerts were set up in each database to receive ongoing notifications of newly published studies that may be relevant for a future umbrella review.

Study Selection

All retrieved records were imported into a reference management tool, and duplicates were removed. Prior to the screening process, a calibration exercise was performed. Two reviewers independently screened a random sample of 25 titles and abstracts to ensure consistency in the application of the eligibility criteria. Inter-rater agreement was calculated using Cohen's kappa statistics, with a threshold of ≥0.80 considered acceptable. Discrepancies were discussed, and the inclusion/exclusion criteria were refined where necessary to improve clarity and consistency. Once calibration was achieved, the two reviewers proceeded to screen all titles and abstracts independently. Full texts of potentially eligible studies were then retrieved and reviewed for final inclusion. Any disagreements were resolved through consensus or by consulting a third reviewer.

Data Extraction

Two reviewers independently extracted data using a standardized form. The following information was collected: (1) author and year of publication, (2) country of origin, (3) study design (in vitro or clinical), (4) type of composite resin, (5) details of glycerin application, (6) light-curing protocol, (7) surface hardness measurement method, (8) storage or clinical conditions prior to testing, (9) surface hardness results (mean and standard deviation), and (10) main findings. When necessary, corresponding authors were contacted to clarify unclear or missing information.

Risk of Bias Assessment

The risk of bias for each included study whether in vitro or clinical in design was independently assessed by two reviewers using a modified version of the RoBDEMAT (Risk of Bias in Dental Materials Testing) tool.[6] This instrument was selected given the focus on material performance outcomes rather than clinical patient-centered effects. The following domains were evaluated: (1) justification of sample size, (2) randomization of specimens or allocation methods, (3) blinding of outcome assessment, (4) standardization of testing procedures, and (5) appropriateness of statistical analysis. Each domain was rated as "Sufficient", "Insufficient", or "Not Reported". Disagreements were resolved through discussion or arbitration by a third reviewer.

Data Synthesis

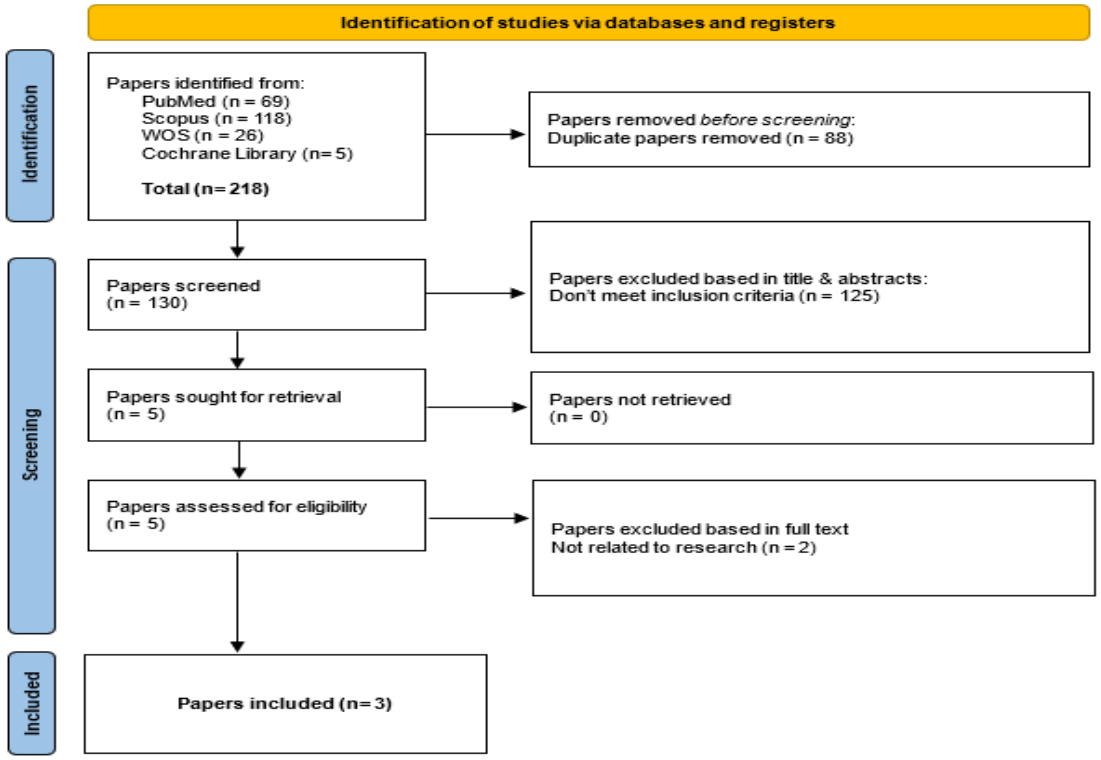
Due to anticipated methodological heterogeneity across the included studies such as differences in composite resin formulations, glycerin application protocols, curing methods, and measurement instruments a narrative synthesis was conducted. Surface hardness results were summarized and compared descriptively between groups with and without glycerin application. Where applicable, clinical and in vitro findings were presented separately.

All extracted data were initially organized and screened in a Microsoft® Excel® spreadsheet, where duplicates, inconsistencies, and incomplete entries were verified. The finalized dataset was then exported to RStudio® 2025.05.0 Build 496 for quantitative analysis. Descriptive statistics were calculated to identify trends in surface hardness outcomes across study groups. No meta-analysis was performed due to considerable variability in study designs, experimental procedures, and reporting formats. All datasets and analysis scripts were made publicly available through Mendeley Data to support transparency and reproducibility.[7]

RESULTS

A total of 218 records were initially identified through electronic database searches: 69 from PubMed, 118 from Scopus, 26 from Web of Science, and 5 from Cochrane Library. No additional records were retrieved from Embase. After the removal of 88 duplicates, 130 records remained for title and abstract screening. Of these, 125 were excluded for not meeting the predefined eligibility criteria. Five full-text articles were assessed for eligibility, with two subsequently excluded for not being research-related. Ultimately, three studies met all the inclusion criteria and were included in the systematic review. (Figure 1)

Figure 1: PRISMA Flowchart for selection studies process



Risk of Bias Assessment

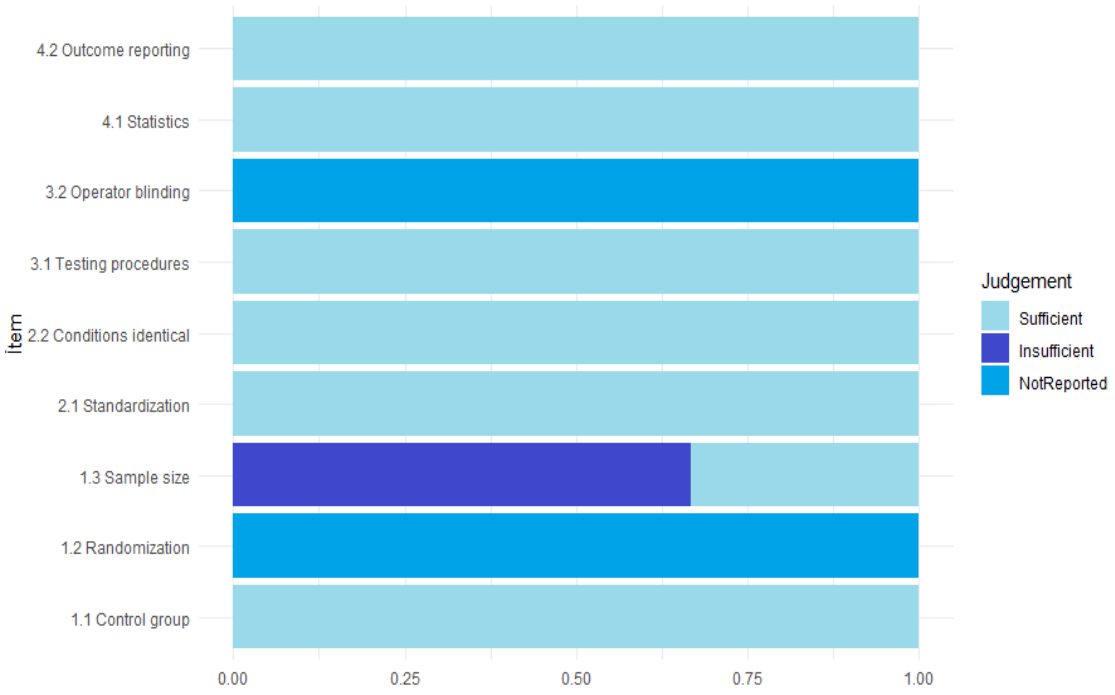
The evaluation of methodological quality across the included studies was conducted using the RoBDEMAT tool, which considers key domains related to internal validity in in vitro investigations. As illustrated in Figure 2, the majority of items were rated as "Sufficient," suggesting an overall acceptable methodological rigor in most evaluated criteria.

Notably, the items "1.2 Randomization" and "3.2 Operator blinding" were consistently rated as "Not Reported" across all studies. This finding highlights a critical gap in the reporting of essential procedures to minimize bias, particularly in the random allocation of specimens and the implementation of operator masking. The absence of such information significantly limits the confidence in the internal validity of the studies included.

In addition, the item "1.3 Sample size" showed a mixed judgment: although partially reported as "Sufficient," a substantial proportion was classified as "Insufficient." This suggests that while some studies provided adequate justification or calculation of sample size, others failed to clearly report or justify their choice, potentially affecting the statistical power of the results.

Conversely, other domains such as "4.1 Statistics," "4.2 Outcome reporting," and all aspects of experimental standardization and testing procedures (Items 2.1 to 3.1) were uniformly judged as "Sufficient," indicating clear reporting and adherence to accepted methodological standards in these areas. (Figure 2)

Figure 2. Overall Risk of Bias Distribution According to RoBDEMAT
Proportional distribution of risk of bias judgments across all RoBDEMAT items evaluated in the included studies. Each bar represents the relative frequency of "Sufficient" (green), "Insufficient" (orange), and "Not Reported" (red) judgments for each item across the dataset. The highest proportions of unreported information were observed in Items 1.2 (Randomization) and 3.2 (Operator blinding), while most studies adequately addressed control group selection, standardization procedures, and statistical analysis.



The methodological quality of the three studies included in the review was assessed using the RoBDEMAT tool, as shown in Figure 3. Overall, the majority of items were rated as "Sufficient," reflecting adequate methodological conduct in several key domains. However, certain critical aspects demonstrated recurrent weaknesses that may influence the reliability of the evidence.

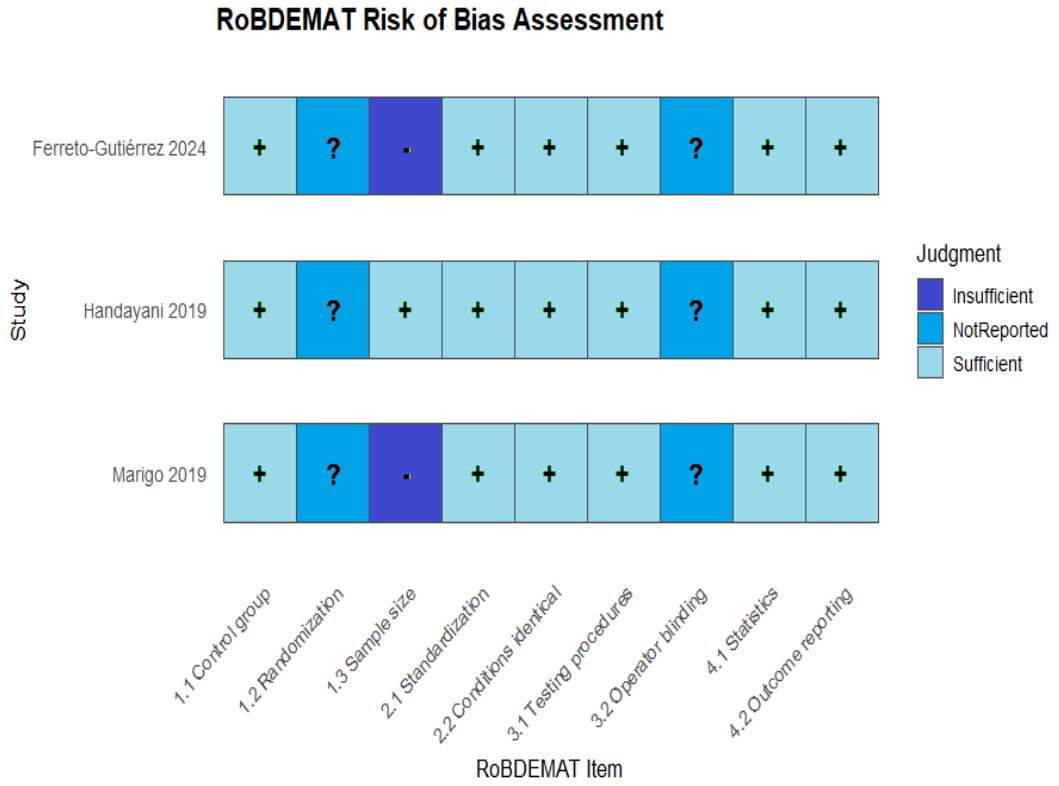
All three studies failed to report adequate procedures for randomization (Item 1.2) and operator blinding (Item 3.2), both of which were consistently rated as "Not Reported." This lack of reporting raises concerns regarding potential selection and performance biases that may compromise the internal validity of the findings.

Two of the studies Ferreto-Gutiérrez *et al.*[8] and Marigo *et al.*[9] also received a judgment of "Insufficient" for sample size (Item 1.3), indicating a lack of justification or calculation, which may have affected statistical power. In contrast, Handayani et al.(10) provided sufficient detail in this domain.

All studies demonstrated adequate performance in domains related to control groups (Item 1.1), experimental standardization (Item 2.1), homogeneity of test conditions (Item 2.2), testing procedures (Item 3.1), statistical analysis (Item 4.1), and reporting of outcomes (Item 4.2), all rated as "Sufficient." These results suggest a general consistency in the execution and reporting of procedural and analytical components.

In summary, although most methodological items were adequately addressed across the included studies, systematic omissions in reporting of randomization and blinding, along with insufficient justification of sample size in some cases, suggest a moderate risk of bias that should be considered when interpreting the synthesized evidence. (Figure 3)

Figure 3. Individual Study-Level Risk of Bias Assessment Using RoBDEMAT
Risk of bias assessment of individual studies based on the RoBDEMAT tool. Each row corresponds to a study, and each column to a specific item evaluated. Green ("+") indicates sufficient methodological reporting, yellow ("-") denotes insufficient reporting, and red ("?") reflects absence of information. While domains such as testing procedures, outcome reporting, and control group use were consistently rated as "Sufficient," all studies failed to report on randomization and operator blinding. Additionally, two studies presented insufficient justification for sample size determination.



The results presented in Table 2 show consistent improvements in surface hardness of composite resins when glycerin was applied prior to light-curing. In the study by Ferreto-Gutiérrez et al.,(8) the application of medical glycerin (KY®) resulted in a markedly higher Vickers hardness value (119 ± 24.4) compared to dental glycerin (75.9 ± 12.03) and the control group without glycerin (68.9 ± 7.8). The findings suggest that medical glycerin was significantly more effective in enhancing polymerization at the surface level, potentially by limiting the oxygen-inhibited layer.

Similarly, Handayani *et al.*[10] observed that glycerin-treated samples showed the highest hardness values (98.12 ± 0.46) compared to other conditions. However, the immersion of specimens in an acidic tamarind soft drink reduced the surface hardness in a time-dependent manner, highlighting the detrimental effects of acidic environments on composite resin surfaces despite initial improvements from glycerin use.

Marigo *et al.*[9] further confirmed that glycerin application prior to curing resulted in enhanced surface hardness across two different resin types Filtek Supreme XTE and CeramX Universal compared with traditional mylar strips and exposure to air or argon. The hardness values increased notably (up to 812 MPa) when oxygen inhibition was minimized, reinforcing the protective and polymerization-enhancing role of glycerin. (Table 2)

Table 2: Summary of In Vitro Studies Evaluating the Effect of Glycerin Application on Surface Hardness of Composite Resins

Author and Year	Country	Type of	Details of Glycerin Application	Light-Curing Protocol	Surface Hardness Measurement Method	Storage or Clinical Conditions	Surface Hardness Results	Main Findings
Ferreto-Gutiérrez (2024) [8]	Costa Rica	Filtek Z350 XT (3M ESPE)	20 s light-curing through medical glycerin (KY®) or dental glycerin (Liquid Strip®)	LED light (Elipar Deep Cure-L, 1505 mW/cm², 450 nm) for 20 s at 1 mm distance	Vickers microhardness (Micromet 2100, Buehler), 19.6N for 20s	Not specified	MG: 119±24.4; DG: 75.9±12.03; CO: 68.9±7.8	Glycerin increases surface hardness. MG > DG ≈ CO; MG significantly improves hardness and reduces C-O/C-H ratio
Handayani (2019) [10]	Indonesia	Filtek Z350 XT (3M ESPE)	0.5 ml applied before curing, cured 20 s, groups immersed in tamarind soft drink or not	LED (Woodpecker F LED-B), 20 s at 0 mm	Vickers hardness tester (VHT 402MVD, Wilson®), 100 gf for 15 s	Some groups immersed in tamarind soft drink (60 or 120 min), some stored dry at 37°C	G: 98.12±0.46; G AS60: 67.34±0.85; G AS120: 61.10±1.39; TG: 72.24±0.91; TG AS60: 63.72±1.21; TG AS120: 54.38±0.9	Glycerin improves hardness; immersion in acidic drink reduces it; non-immersed glycerin group highest hardness
Marigo (2019) [9]	Italy	Filtek Supreme XTE and	Glycerin applied before light-curing, compared with mylar strip, argon, and air	LED (BlancOne IDS, 2200 mW/cm²), 20 s at 1 mm	Vickers microhardness (MHT4, Zeiss), 100 g for 10 s	Specimens stored in water, coffee, red wine (28 d at 37°C)	CX: ~570–>800 MPa; XTE: up to 812 MPa with argon	Oxygen exposure reduces hardness; curing with glycerin improves hardness and color stability

DISCUSSION

The findings of this systematic review revealed a consistent positive effect of glycerin application prior to light-curing on the surface hardness of dental composite resins. Across the three included in vitro studies, samples treated with glycerin demonstrated significantly higher hardness values compared to untreated controls. This effect was primarily attributed to the ability of glycerin to minimize the OIL, thereby enhancing the polymerization process at the surface level.

Notably, the study by Ferreto-Gutiérrez *et al.*[8] showed that medical-grade glycerin was more effective than dental glycerin in improving surface hardness, suggesting that the specific formulation and purity of glycerin may influence its efficacy. In contrast, Handayani *et al.*[10] demonstrated that although glycerin application initially improved hardness, subsequent exposure to acidic environments diminished this benefit in a time-dependent manner. This underscores the vulnerability of composite resins to extrinsic degradation despite enhanced polymerization. Similarly, Marigo *et al.*[9] confirmed that the use of glycerin surpassed the performance of other oxygen-blocking methods, such as Mylar strips and inert gas curing, in terms of increasing hardness values and maintaining color stability.

Although the role of glycerin in enhancing surface hardness is well documented, it is important to consider that the specific formulation and purity of glycerin may influence its performance. Variations in its chemical composition or the presence of impurities could alter its effectiveness in reducing the oxygen-inhibited layer and improving polymerization. Therefore, ensuring high purity and an appropriate formulation of glycerin is crucial to achieve optimal results in dental applications.[1,11,12]

Although the study by Chen *et al*.[13] examined the moisture retention capacity of glycerin in cosmetic products at concentrations ranging from 0 % to 70 %, and Bhat *et al*.[14] demonstrated that glycerin solutions between 50 % and 75 % were optimal for dissolving dental plaque achieving dissolution rates of approximately 30% at a 90% concentration no studies similar to that of Ferreto-Gutiérrez *et al*.[8] were identified at the time this investigation was concluded, specifically addressing the optimal glycerin concentration to enhance the polymerization of composite resins.

Effect of glycerin application on surface hardness of composite resins

The application of glycerin prior to light-curing was consistently associated with enhanced surface hardness of composite resins. This outcome was primarily attributed to the ability of glycerin to act as an oxygen barrier, thereby preventing the formation of the OIL on the resin surface. The OIL, which results from the interaction between atmospheric oxygen and free radicals during polymerization, has been shown to compromise the degree of conversion and reduce surface hardness, leading to increased susceptibility to degradation and microleakage.[1]

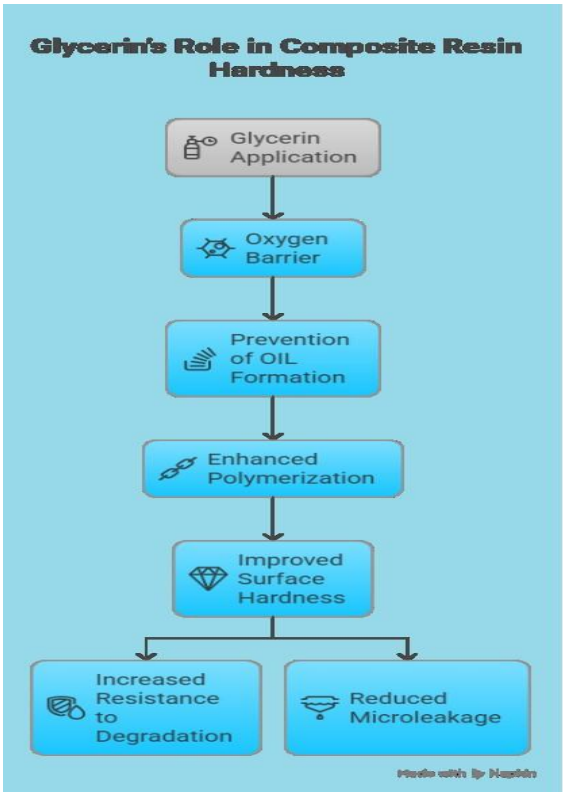
In the study by Gonçalves *et al*.,[15] the use of glycerin significantly improved the degree of conversion across all tested composite resins (bulk-fill, nanoparticle, and microhybrid), irrespective of the assessment time (immediate or after 15 days). These findings indicated that glycerin minimized oxygen interference during polymerization, facilitating the formation of a more complete polymer network, which likely translated into improved surface mechanical properties such as hardness.

Similarly, the work of Park and Lee[1] demonstrated that glycerin application prior to curing resulted in significantly higher surface hardness in unpolished specimens compared to those cured in air. Although polishing itself was the most effective method to enhance hardness by removing the OIL, glycerin application offered a clinically feasible alternative for areas where polishing is not possible, such as occlusal pits and fissures.

Mardianti *et al*.[16] also supported the positive role of glycerin in enhancing hardness, highlighting its effectiveness both in hybrid and nanofill composites. The literature reviewed emphasized that free radicals, if not scavenged by atmospheric oxygen, are able to fully react with monomers, promoting a more complete polymerization process. The inhibition of OIL formation by glycerin thus translated into a denser and harder surface layer.

Furthermore, Nugroho *et al*.[2] confirmed that even after immersion in alcoholic mouthwash a condition known to degrade composite resins samples treated with glycerin before curing exhibited significantly higher surface hardness compared to untreated controls. This suggests that glycerin not only enhances initial polymerization but may also confer greater resilience to subsequent chemical challenges. The content summarized in Figure 4 is presented.

Figure 4. Glycerin role in composite resin hardness



In the present review, the commercial formulations of glycerin used in each study varied, potentially contributing to the differences observed in surface hardness outcomes. Ferreto-Gutiérrez *et al.*[8], employed two distinct types of glycerin: KY®, a medical-grade formulation, and Liquid Strip®, a dental-specific product, reporting that KY® resulted in the greatest enhancement of surface microhardness. In contrast, Handayani *et al.*[10] applied glycerin topically before curing but did not disclose the commercial brand used, limiting the ability to assess product-specific effects. Marigo *et al.*[9] utilized Shiny G Air block (Micerium, Italy), a proprietary glycerin-based barrier delivered via single-use tips, which effectively minimized oxygen inhibition and improved hardness and color stability of the composite materials. These discrepancies in glycerin composition and application methods underscore the need for standardization when evaluating the impact of glycerin on resin polymerization outcomes.

This systematic review had some limitations that should be acknowledged. The number of eligible studies was relatively small, which limited the breadth of the evidence and precluded the performance of a quantitative meta-analysis. As a result, the conclusions were based on a narrative synthesis, which may be less robust than statistical aggregation.

Moreover, all included studies were conducted in vitro, without replication of intraoral conditions such as moisture, temperature variation, or mechanical load. This may restrict the direct applicability of the findings to clinical practice. It should be noted that the scope of this investigation was initially designed to include clinical studies; however, none were identified at the time the review was conducted.

The methodological assessment also revealed gaps in reporting. None of the studies clearly described the random allocation of specimens or blinding of outcome assessment, which may introduce some degree of selection or performance bias. Additionally, sample size justification was lacking or insufficient in two of the studies, potentially affecting the reliability of the statistical comparisons.

Variability in experimental protocols, including differences in resin types, glycerin application techniques, light-curing parameters, and storage media, also posed challenges to direct comparability. Further studies with standardized methodologies and better reporting practices would be helpful to validate and extend these findings.

CONCLUSIONS

This systematic review provided evidence that glycerin application before light-curing consistently enhanced the surface hardness of composite resins in vitro. The improvement was primarily attributed to the reduction of the oxygen-inhibited layer, promoting a more complete polymerization process. Despite certain methodological limitations, the consistency of results across various composite types and testing protocols reinforced the plausibility of these benefits. Nevertheless, the potential influence of environmental factors and variability in glycerin formulations underscores the need for high-quality studies conducted under clinically simulated conditions. Such investigations are essential to confirm these findings and to inform standardized protocols for clinical application.

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Conflict of interests

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Authors´ contributions

Alain Manuel Chaple Gil: Concepts; data curation; analysis; research; methodology; project administration; software; supervision; validation; display; writing - original draft; drafting - revision and editing.

Lazareth Liz Ortiz Santiago: Data curation; research; methodology; software; validation; display; writing - original draft.

Laura Pereda Vázquez: Analysis; research; methodology; validation; display; writing - original draft; drafting - revision and editing.

Meylin Santiesteban Velázquez: Data curation; analysis; research; validation; display; writing - original draft; drafting - revision and editing.

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