THE INFLUENCE OF DENTAL BLEACHING TECHNIQUES ON MICROLEAKAGE OF COMPOSITE RESIN RESTORATION: A SYSTEMATIC REVIEW

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Abstract:
Dental bleaching is a popular and conservative aesthetic technique used to whiten discolored teeth. However, there are concerns about the adverse effects of bleaching on composite restorations, such as color change, decreased bond strength, and microleakage. This review aims to evaluate the influence of tooth bleaching on composite restoration microleakage and to investigate the suggested methods used to prevent microleakage in composite restorations. A comprehensive search was conducted using four databases - PubMed, Scopus, Web of Science, and EBSCOhost - using a list of core keywords that included: ((Bleaching OR Whitening) AND ("dental adhesives" OR bonding OR "total-etch" OR "Self-etch" OR "total etch" OR "Self etch") AND (Dental OR Enamel OR Dentin)). The inclusion criteria were in-vitro experiments written in English that involved composite restoration microleakage as the primary outcome due to bleaching. Of 1524 articles from the initial search, 18 were eligible for this review. Among the two major groups included in the study, the post-restorative bleaching group demonstrates highly varied results on the occurrence of microleakage. Conversely, the pre-restorative bleaching group indicates that bleaching materials can adversely affect the marginal integrity of the composite restoration. It was suggested that the resulting microleakage can cause problems such as recurrent caries and postoperative hypersensitivity and may be due to the natural bleaching mechanism depending on the oxidation reaction to remove the stains on the tooth surface. This releases oxygen and free radicals, and the residual oxygen on the tooth surface may inhibit the resin polymerization and lead to microleakage but can be overcome by the help of antioxidant materials, such as sodium ascorbate. This review provides substantial evidence from the literature on the preventive mechanism of composite microleakage and precautionary techniques when bleaching on composite restorations.

Keywords: Composite Resins, Dental Restoration, Microleakage, Tooth Bleaching.

Introduction

The dental bleaching procedure is one of the most popular and conservative aesthetic techniques employed by dentists using whitening agents to remove discoloration present on the tooth surface (1-3). Tooth discolorations may be caused by intrinsic stains that reflect on the tooth surface due to various factors, such as pulp necrosis, root resorption, intra-pulpal hemorrhage, or drug-related factors like tetracycline. Extrinsic stains can result from chlorhexidine or metal salts, smoking, or consuming foods and drinks rich in tannic acid and plaque (1). There are two techniques for bleaching, extracoronal and intracoronal, which employ different concentrations of bleaching materials (4, 5). Moreover, bleaching materials contain hydrogen peroxide as the active component, which is a strong oxidizing agent provided in the form of hydrogen peroxide or carbamide peroxide (3), as well as inactive components include surfactants, carriers, pigments, thickening agents, and preservatives (1, 6). During the bleaching process, hydrogen peroxide decomposes into oxygen atoms and free radicals, which in turn dissolve the large-colored molecules into smaller, less-colored ones (7).

In dental practice, it is common to encounter teeth that require whitening followed by direct or indirect restorative treatments to fulfil aesthetic demands (8, 9). Despite the beneficial outcomes achieved through the bleaching process, concerns regarding its impact on composite restorations exist. Numerous studies have demonstrated that bleaching materials can cause changes in the tooth surface and adversely affect the restoration's color stability, bonding strength, surface roughness, and porosity (10-12). Furthermore, Attain et al. have documented that bleaching has the potential to result in microleakage in resin composite restorations (12). It has been suggested that the residual oxygen remaining on the tooth surface following the bleaching process is considered the primary cause of increased microleakage (13, 14). Consequently, some studies have proposed using antioxidants to eliminate the oxygen residues on the tooth surface (15, 16). Furthermore, these changes in the tooth tissues are reversible and time-dependent (17). Therefore, allowing sufficient time to elapse after the bleaching process may enhance outcomes and prevent microleakage (13). Microleakage can give rise to various clinical issues, including bacterial infiltration leading to recurrent caries, pulp irritation, postoperative hypersensitivity, and subsequent restoration failure (18).

Undoubtedly, aesthetics is a significant concern in dentistry, and direct resin composite restoration or bleaching is one of the primary approaches to enhance it. However, there is limited evidence available regarding the impact of the bleaching procedure on the microleakage of composite restorations, as reported in the previous study (2). Furthermore, the lack of research on optimal methods for combining these procedures while considering the effect of bleaching on microleakage remains controversial. Given the variations in bleaching techniques found in the literature, this study aims to assess the influence of tooth bleaching on the microleakage of composite resin restorations and to investigate the suggested methods used to prevent microleakage in composite restorations.

Materials and Methods

This systematic review followed the PRISMA guideline, "Preferred Reporting Items for Systematic Reviews and Meta-Analyses". Additionally, the methodological details of this study were registered on the PROSPERO website, the International Prospective Register of Systematic Reviews (CRD42023396921). The research question formulated for this study is as follows: What is the impact of various dental bleaching techniques on the microleakage of composite resin restorations in teeth?

Search strategy and definitions

This search was conducted following the PICO strategy, where participants (P) were human or bovine extracted teeth, intervention (I) involved dental bleaching materials in conjunction with composite restoration, comparison (C) comprised composite restored teeth that had not undergone bleaching, and the outcome (O) was microleakage of the composite restoration.

Selection Criteria

A comprehensive search was conducted across four databases: MEDLINE (PubMed), Scopus, Web of Science, and EBSCOhost. The core list of keywords utilized included: (Bleaching OR Whitening) AND ("dental adhesives" OR bonding OR "total-etch" OR "Self-etch" OR "total etch" OR "Self etch") AND (Dental OR Enamel OR Dentin).

Inclusion criteria

- In vitro experiments written in English.
- Studies involving composite restoration microleakage as the primary outcome resulting from bleaching.
- Studies conducted on human or bovine extracted teeth.
- Articles published from the year 2000.

Exclusion criteria

- Studies that did not involve composite as the restoration material.
- Studies that reported bond generation failure.
- Studies that did not include a microleakage score.
- Studies with insufficient information or unavailable full text.

Study Selection

After conducting electronic research on the four databases performed by two independent reviewers (Y.M. and I.N.B), the resulting data was imported into Endnote X8 and exported to a Microsoft Excel sheet using a specific style. All duplicated articles were eliminated through the joint efforts of two independent reviewers (A.A. and R.H.). Based on the title and abstract, the remaining results underwent screening by two independent reviewers (B.S. and G.R.). In cases where there were differences of opinion between the reviewers, two reviewers (Y.M. and I.N.B) were consulted. Articles deemed eligible during the screening were selected for full-text review and subsequent data extraction.

Data Extraction

Three reviewers (Y.M., A.A., and G.R.) extracted the required methodological information from the included articles. The following information was collected: main characteristics (study authors, study design, study year, and country), total sample size, tooth types, target tooth structure, the initial procedure performed on the samples (bleaching or cavity restoration), the bleaching material used, composite type, bonding procedure, adhesive generation, cavity design, the measuring method used to assess microleakage, and the specific microleakage scores employed.

Risk of Bias Assessment

The risk of bias (ROB) was assessed by three reviewers (Y.M., R.H., and B.S.) using a previously adapted ROB tool from other systematic reviews, including in vitro studies (19, 20). The following parameters were evaluated: randomization process, sample size calculation, comparability of groups, detailed measurement information, appropriate statistical analysis, adherence to manufacturer's instructions, single operator, and blinded operator. A "Yes" was assigned if each domain was judged as positive, while a “No” was assigned if it was not present in the entire article. The overall risk of bias for each article was determined by counting the number of “Yes” responses, categorized as follows: 1 to 3 “Yes” (high risk of bias), 4 to 5 “Yes” (medium risk), and 6 to 8 “Yes” (low risk). Inter-evaluator reliability was assessed using Kappa statistics.

Table 1: Search strategy for literature

Database	Search string	Limits / Inclusion
SCOPUS	(TITLE-ABS-KEY ((bleaching OR whitening)) AND TITLE-ABS-KEY (("dental adhesives" OR bonding OR "total-etch" OR "Self-etch" OR "total etch" OR "Self etch")) AND TITLE-ABS-KEY ((dental OR enamel OR dentin)))	Document: Articles Stage: Final Timespan: All years
Web of Science	(bleaching OR whitening) (Topic) AND ("dental adhesives" OR bonding OR "total-etch" OR "Self-etch" OR "total etch" OR "Self etch") (Topic) AND (dental OR enamel OR dentin) (Topic)	Timespan: All years
PubMed	(“bleach”[All Fields] OR “bleached”[All Fields] OR “bleaches”[All Fields] OR “bleaching”[All Fields] OR “bleachings”[All Fields] OR (“whiten”[All Fields] OR “whitened”[All Fields] OR “whitener”[All Fields] OR “whiteners”[All Fields] OR “whitening”[All Fields] OR “whitens”[All Fields])) AND (“dental adhesives”[All Fields] OR (“bonded”[All Fields] OR “bondings”[All Fields] OR “bonds”[All Fields] OR “object attachment”[MeSH Terms] OR (“object”[All Fields] AND “attachment”[All Fields]) OR “object attachment”[All Fields] OR “bonding”[All Fields]) OR “total-etch”[All Fields] OR “self etch”[All Fields] OR “total-etch”[All Fields] OR “self etch”[All Fields]) AND (“dental health services”[MeSH Terms] OR (“dental”[All Fields] AND “health”[All Fields] AND “services”[All Fields]) OR “dental health services”[All Fields] OR “dental”[All Fields] OR “dentally”[All Fields] OR "dentals"[All Fields] OR ("dental enamel"[MeSH Terms] OR ("dental"[All Fields] AND "enamel"[All Fields]) OR "dental enamel"[All Fields] OR "enamel"[All Fields] OR "enamels"[All Fields] OR "enamel s"[All Fields] OR "enameled"[All Fields] OR "enameling"[All Fields] OR "enamelling"[All Fields]) OR ("dentin"[MeSH Terms] OR "dentin"[All Fields] OR "dentine"[All Fields] OR "dentines"[All Fields] OR "dentins"[All Fields] OR "dentin s"[All Fields] OR "dentinal"[All Fields] OR "dentine s"[All Fields]))	Timespan: All years
EBSCOHost	((Bleaching OR Whitening) AND ("dental adhesives" OR bonding Or "total-etch" Or "Self-etch" OR "total etch" OR "Self etch") AND (Dental OR Enamel OR Dentin)) OR AB ((Bleaching OR Whitening) AND ("dental adhesives" OR bonding OR "total-etch" Or "Self-etch" OR "total etch" OR "Self etch") AND (Dental OR Enamel OR Dentin))	Timespan: All years

Result

Study Selection and Flow Diagram

The initial search was conducted on November 10, 2022, resulting in 1,524 articles from the four databases. Among these, 794 articles were identified as duplicates and were subsequently removed. An additional 701 articles were excluded based on the predefined inclusion criteria (Agreement between reviewers was high, K = 0.89). A total of 29 articles underwent full-text screening, out of which 14 met the eligibility criteria for inclusion in our systematic review. The remaining 12 articles were excluded for various reasons (Agreement between reviewers was high, K = 0.87). Furthermore, four additional articles deemed eligible for inclusion in our study were obtained from the reference lists and websites. Figure 1 presents a flow diagram that summarises the screening process following the PRISMA statement.

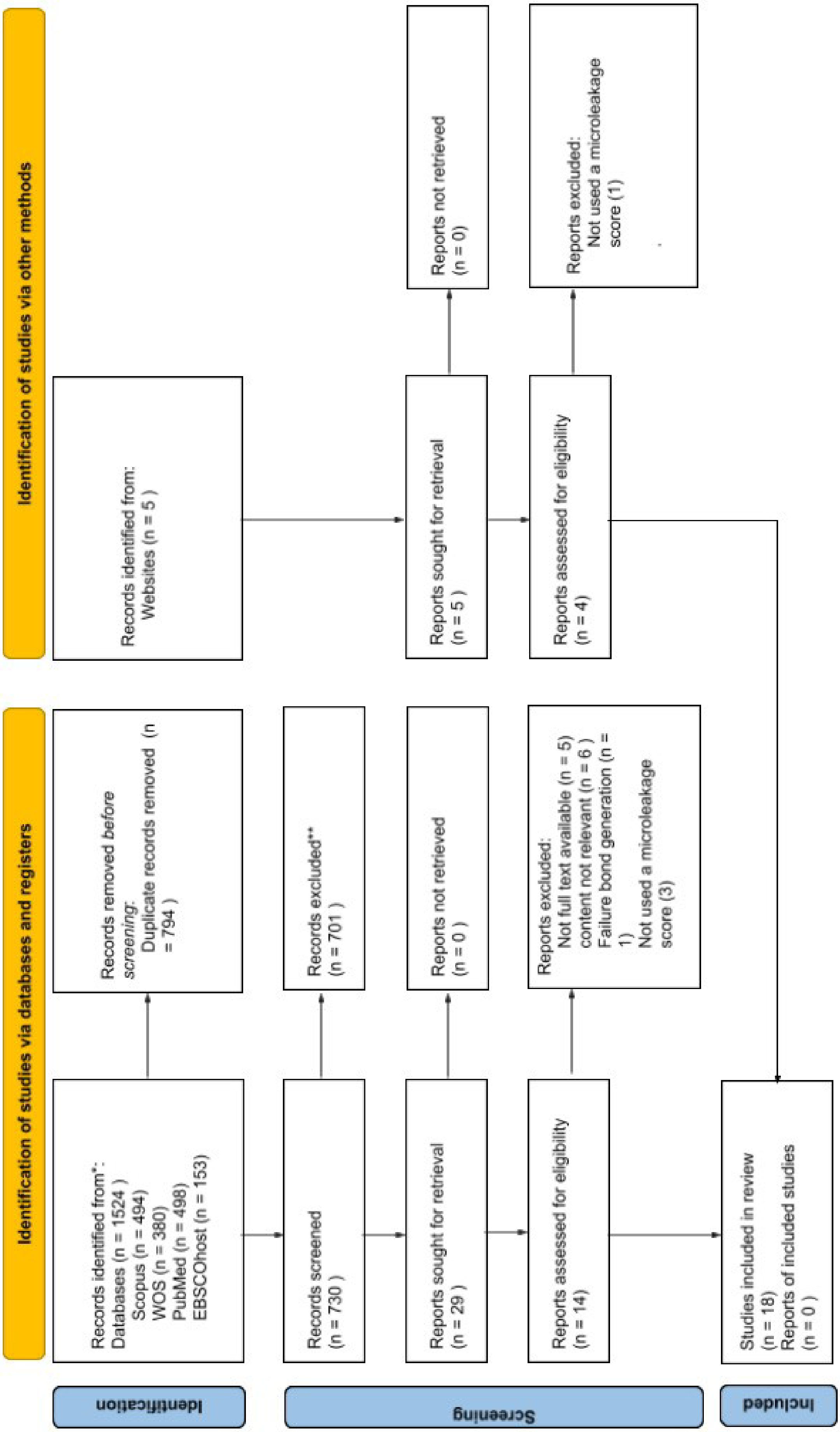

Figure 1: Summary of study selection process for systematic review

Characteristics of the Studies

Eight of the 18 articles involved bleaching as the initial procedure in the sample studies, while the remaining ten focused on restoration. The total number of teeth included in the analysis was 1,242; with 1,508 cavities identified. Among these, 408 were access cavities, as reported in three articles (13, 16, 21), 266 were located on the lingual aspect, and 834 were found on the buccal aspect of class V cavities, as reported in the rest of the studies. All studies measured microleakage on the enamel surface, while 12 assessed both enamel and dentin/cementum. The tooth types utilized in the studies included anteriors, premolars, and molars. Human-extracted teeth were used in all selected studies except for two studies that employed bovine teeth (13, 22). Microleakage was evaluated using the dye penetration technique in all articles, and the microleakage scores were assessed under a microscope after longitudinal sectioning of the samples. The studies predominantly utilized carbamide peroxide and hydrogen peroxide as the main bleaching materials. Table 2 provides an overview of the characteristics of the included studies.

Table 2: Study Characteristics

Study	First procedure	Teeth type	Cavity design	Substrate	Dye type	The using score	Intacoronal or extra coronal bleaching	Bleaching material
Bektas et al. 2013 (26)	Restoration	Premolar	Class V	Enamel + dentine	0.5% Fuchsin solution	0= No marginal leakage 1= within 1/3 of the cavity wall 2= to 2/3 of the cavity wall 3= the last 1/3 of the cavity wall without reaching the axial wall 4= spreading along the axial wall	Extracoronal	10% Carbamide peroxide + 38% hydrogen peroxide
Bulucu et al. 2008 (7)	Bleaching	Molar	Access cavity	Enamel + dentine	0.5% basic fuchsin	0= No leakage 1= leakage at the gingival wall 2= leakage at the cavity base	Extracoronal	16% Carbamide peroxide
Demarco et al. 2001 (23)	Bleaching	Incisor	Class V	-	0.5% methylene blue	0= No dye penetration 1= Dye up to half of the cavity wall depth 2= Dye leakage greater than half of the cavity wall depth	Intracoronal	Sodium perborate + 30% hydrogen peroxide
Han et al. 2014 (15)	Bleaching	Premolar	Class V	Enamel + dentine	2% Methylene blue	0= No leakage 1= Dye up to half of the cavity wall depth 2= Dye penetration greater than half of the cavity wall depth 3= Involving the base of the cavity	Extracoronal	10% Carbamide peroxide
Hashemikamangar et al. 2014 (27)	Restoration	Premolar	Class V	Enamel + dentine	2% Fuchsin solution	0= No dye penetration 1= Up to 1⁄2 of the gingival/occlusal wall 2= More than 1⁄2 3= Extending into the axial wall and pulp	Extracoronal	30% Hydrogen peroxide

Table 2: Study Characteristics (continued)

Study	First procedure	Teeth type	Cavity design	Substrate	Dye type	The using score	Intacoronal or extra coronal bleaching	Bleaching material
Iovan et al. 2018 (28)	Restoration	Molar	Class V	Enamel + dentine	1% Methylene blue	0= No dye penetration 1= From the cavosurface margin to less than 1/2 the length of the prepared wall 2= From cavosurface angle to more than 1/2 the length of the prepared wall 3= From cavosurface margin along the whole length of the prepared wall and involve the axial wall	Extracoronal	40% Hydrogen peroxide
Khoroushi et al. 2009 (29)	Restoration	Premolar	Class V	Enamel + dentine	.5% Basic fuchsin	0= No microleakage 1= Up to one-third of cavity depth 2= Penetration between 1/3 and up to 2/3 of cavity depth 3= Penetration of more than 2/3 of cavity depth and up to the axial wall or toward the pulp	Extracoronal	30-35% Hydrogen peroxide
Klein Jr et al. 2018 (22)	Restoration	Anterior	Class V	Enamel	0.1 M Rhodamine B solution	0= No dye penetration 1= Covering less than half of the distance to the axial wall 2= Covering more than half of the distance to the axial wall but not reaching the axial wall 3= Dye penetration into the axial wall	Extracoronal	20% Carbamide peroxide + 40% Hydrogen peroxide
Klukowska et al. 2008 (30)	Restoration	Molar	Class V	Enamel + dentine	0.1% Rhodamin-B solution	0 = No dye penetration 1= Up to 1/3 of cavity depth 2= Up to 2/3 cavity depth 3= Up to the base of the cavity 4= Up into the axial wall	Extracoronal	14% Hydrogen peroxide
Meshkinnejad et al. (24)	Bleaching	Premolar	Class V	Enamel + dentine	2% Fuchsin solution	0= No microleakage 1= ½ Depth of the cavity wall 2= Beyond the 1/2 depth of the cavity wall 3= Reached the cavity bottom surface	Extracoronal	35% Hydrogen peroxide

Table 2: Study Characteristics (continued)

Study	First procedure	Teeth type	Cavity design	Substrate	Dye type	The using score	Intacoronal or extra coronal bleaching	Bleaching material
Moosavi et al. 2010 (21)	Bleaching	Incisor	Access cavity	-	0.5 % Fuchsin solution	0=No leakage 1= Up to half of the cavity wall depth 2= Greater than half of the cavity wall depth 3=Iinvolving the root canal filling	Intracoronal	10% Carbamide peroxide
Moosavi et al. 2009 (31)	Restoration	Molar	Class V	Enamel + dentine	0.5% Basic fuchsin	0= No dye penetration 1= Into half of the extension of the occlusal or gingival wall 2= Into a complete extension of the occlusal or gingival wall 3= Into the axial wall	Extracoronal	15% Carbamide peroxide
Mortazavi et al. 2011 (32)	Restoration	Anterior	Class V	Enamel + dentine	0.5 % Fuchsin solution	0= No dye penetration 1= Covering less than half of the distance to the axial wall 2= Covering more than half of the distance to the axial wall but not reaching the axial wall 3= Into the axial wall	Extracoronal	15% Carbamide peroxide
Roubickova et al. 2013 (33)	Restoration	Molar	Class V	Enamel + dentine	2% Methylene blue	0 = No dye penetration 0.5 = Up to 1/4 of the cavity depth 1= Up to 1/2 of the cavity depth, typically equal to the whole depth of the enamel layer on the enamel margin 2= Over one-half of the cavity depth to its floor 3= Including the cavity floor	Extracoronal	20% Carbamide peroxide
Teixeira et al. 2003 (13)	Bleaching	-	Access cavity	-	2% Methylene blue	0= No dye penetration 1= Only in enamel 2= Dye penetration through both enamel and dentine	Intracoronal	30% Hydrogen peroxide with sodium perborate or sodium perborate alone, or 37% carbamide peroxide alone

Table 2: Study Characteristics (continued)

Study	First procedure	Teeth type	Cavity design	Substrate	Dye type	The using score	Intacoronal or extra coronal bleaching	Bleaching material
Türkün et al.2004 (16)	Bleaching	Incisor	access cavity	-	India ink	0= No leakage 1= Up to half of the cavity wall depth 2= Greater than half of the cavity wall depth 3= Involving the root canal filling	Intracoronal	10% Carbamide peroxide
Yazici et al. 2010 (25)	Bleaching	Premolar	class V	Enamel	0.5% Fuchsin solution	1= Up to 1/3 of cavity depth 2= Up to 2/3 of cavity depth 3= To the full depth of cavity depth 4= Into the axial wall of the cavity	Extracoronal	10% Carbamide peroxide
Yu et al. 2010 (9)	Restoration	Molar	Class V	Enamel + dentine	0.5% Basic fuchsin	(For enamel) 0= No microleakage 1= Within the enamel of the occlusal wall 2= Reaching the dentin of the occlusal wall up to the axial wall 3= Spreading along the axial wall (For dentine) 0= No microleakage 1= Up to halfway along the gingival wall 2= Within the gingival wall up to the axial wall without reaching the axial wall 3= Spreading along the axial wall	Extracoronal	10% Carbamide peroxide

The outcome of the intervention approach

This review's primary focus was evaluating the impact of pre-restorative and post-restorative bleaching techniques on the microleakage of composite resin restoration within tooth cavities. The marginal integrity of the study samples was obtained through longitudinal sectioning and assessed using the dye penetration method. All studies employed microleakage scores between the control and intervention groups to compare the results. These scores varied among the included analyses, as outlined in Table 2.

Various approaches were employed in the studies to prevent microleakage. These included using a time-elapsed approach, applying antioxidants such as sodium ascorbate, antioxidants with a surfactant, and castles in the pre-restorative bleaching group. Additionally, several suggestions were made in the postoperative bleaching group, including using high-quality composite types or adhesive systems that exhibit high sealing resistance to overcome microleakage. Considering these diverse recommendations, this review outlines the approaches that enhance the primary outcome.

Risk of bias assessment

Out of the 18 included articles, seven were classified as low risk, while 11 were categorized as medium risk according to the risk of bias assessment. Table 4 provides a detailed description of the risk of bias assessment results, following the analysis parameters. Among the studies, the items that received the highest number of "no" scores were sample size calculation and single operator, respectively

Table 3: The intervention techniques

Study	Control	Intervention groups	Conclusion
Bektas et al. 2013 (26)	Non-bleached group (Clearfil SE bond; Prime & bond NT)	Bleached group using 10% carbamide peroxide with (Clearfil SE bond; Prime & bond NT) Bleached group using 38% hydrogen peroxide with (Clearfil SE bond; Prime & bond NT) Bleached group using Smartbleach with (Clearfil SE bond; Prime & bond NT)	The influence of the post-restorative bleaching on microleakage differs according to the bleaching material used, not the type of bond used, where microleakage is increased by using laser-activated bleaching, and at-home bleaching increases the dentine microleakage than enamel, but the two used adhesive systems themselves did not show a difference in microleakage when treated with the same type of bleaching system
Bulucu et al. 2008 (7)	Non bleached (QTH)* group with (Prime & bond NT; Single bond 2) Non bleached (LED)* group with (Prime & bond NT; Single bond 2) Non bleached (PAC)* group with (Prime & bond NT; Single bond 2)	Bleached QTH group with (Prime & bond NT; Single bond 2(Bleached LED group with (Prime & bond NT; Single bond 2(Bleached PAC group with (Prime & bond NT; Single bond 2)	Microleakage after immediate application of composite restoration following the bleaching procedure cannot be avoided regardless of the light curing source or the type of adhesive system used in composite restoration
Demarco et al. 2001 (23)	Non-bleached group and wait 7 days for the final restoration	Bleached group used walking bleaching materials, which placed for 7 days after that (the bleaching materials were removed and apply the final restoration; the bleaching materials were removed and place calcium hydroxide as a temporary filling for another 7 days then final restoration)	The walking bleaching technique increases the microleakage, but the use of calcium hydroxide as a temporary filling does not increase microleakage after bleaching
Han et al. 2014 (15)	Non bleached group	Immediate restoration group after bleaching Delayed restoration group for 3 weeks after bleaching Bleached group was then applied immediately for 1 minute before restoration (10% sodium ascorbate; sodium ascorbate combined with surfactant; catalase)	Treatment with sodium ascorbate combined with surfactant and catalase is more effective than a delayed filling or sodium ascorbate in decreasing microleakage produced by 10% carbamide peroxide.
Hashemikamangar et al. 2014 (27)	Non bleached group with (FiltekZ250 with Prompt L-Pop group; FiltekZ350 with Prompt L-pop group; FiltekP90 with P90 adhesive group)	Bleached group with (FiltekZ250 with Prompt L-Pop; FiltekZ350 with Prompt L-pop; FiltekP90 with P90 adhesive)	Compared between Z250 and P90 composite, there is no difference in enamel and dentine microleakage of both control and bleaching groups, but Z350 reduced microleakage at the gingival margin that is not noted compared with the control group and no significant difference at the occlusal margin
Iovan et al. 2018 (28)	Non-bleached group with (total-etch; self-etch)	Bleached group with (total-etch; self-etch)	The microleakage of the composite after bleaching with 40% hydrogen peroxide demonstrates no significant difference compared to control groups at both cervical and enamel margins. The etching strategy did not significantly affect the ability of the universal bond to seal the margins of restoration after bleaching

Table 3: The intervention techniques (continued)

Study	Control	Intervention groups	Conclusion
Khoroushi et al. 2009 (29)	Single bond adhesive with Z100 resin composite non-bleached group	Single bond adhesive with Z100 resin composite bleached group using hydrogen peroxide activated by plasma arc unit	Activation of bleaching agent by plasma arc unit does not significantly affect the marginal integrity of composite
Klein Jr et al. 2018 (22)	Non-bleached group with (single bond; SE bond)	20% Carbamide peroxide bleached group with (Single bond; SE bond) 40% Hydrogen peroxide bleached group with (Single bond; SE bond)	Whatever the type of adhesive used, both at home and the office, bleaching causes microleakage on the restoration
Klukowska et al. 2008 (30)	Non-bleached group dipped in (CCP)* dentifrice	Crest Whitestrips group contains 14% hydrogen peroxide and is treated with (CCP) Opalescence PF group contains 20% carbamide peroxide and is treated with (CCP) Opalescence Xtra Boost group contains 38% hydrogen peroxide and is treated with (CCP)	The post-restorative bleaching has almost no effect on the microleakage of composite restoration
Meshkinnejad et al. (24)	Non bleached group	Immediate restoration group after bleaching Delayed restoration group for 2 weeks after bleaching Bleached group was then applied immediately for 10 minutes before restoration (10% sodium ascorbate group, ascorbic acid group, vitamin C group)	Delay restoration for 2 weeks or immediate application of antioxidants (sodium ascorbic, ascorbic acid, and vitamin C) can prevent microleakage like non-bleaching teeth
Moosavi et al. 2010 (21)	Non bleached group	Immediate restoration group after bleaching Bleached group was then applied immediately for 3 hours before restoration (10% sodium ascorbate; 10% sodium ascorbate with surfactant)	The addition of 10% sodium ascorbate with a surfactant to the bleaching teeth decreases the microleakage significantly
Moosavi et al. 2009 (31)	Non bleached group	Post-restorative bleaching, then stored in artificial saliva for (one day; one week; two weeks)	The bleaching by 15% carbamide peroxide after restoration will increase the microleakage in dentinal margins
Mortazavi et al. 2011 (32)	Non-bleached group with (Scotch bond; Prompt L Pop; iBond)	Bleached group with (Scotch bond; Prompt L Pop; iBond)	The L Pop bond increases dentinal microleakage significantly in bleached teeth, and the scotch bond gives the most preferred sealing and least microleakage in both enamel and dentin, whereas iBond causes the most enamel microleakage in the control group
Roubickova et al. 2013 (33)	Non-bleached group with (Gluma Comfort bond; Adper Prompt bond; Clearfil SE bond; iBond (Gluma inside))	Bleached group with (Gluma Comfort bond; Adper Prompt bond; Clearfil SE bond; iBond (Gluma inside))	All etch and rinse Gluma Comfort bond groups had low microleakage and were not significantly influenced by bleaching, whereas the two-step self-etch Clearfil SE bond control group recorded low microleakage, but after bleaching, a slight significant increase in microleakage at the enamel margin happened, in contrast, the microleakage was significantly higher at the enamel margins in one-step self-etch Adper Prompt bond and ibond control groups and more increased that at the dentin margins

Table 3: The intervention techniques (continued)

Study	Control	Intervention groups	Conclusion
Teixeira et al. 2003 (13)	Non-bleached groups with four intervals of time (baseline; 7; 14; 21 days)	Bleached group with (sodium perborate with 30% hydrogen peroxide; sodium perborate with distilled water; carbamide peroxide) were applied at four intervals times (baseline; 7; 14; 21 days)	At baseline and 7 days, the sodium perborate with 30% hydrogen peroxide group demonstrated a higher microleakage than the control group, whereas, at 14 and 21 days, there were no differences among all intervention and control groups
Türkün et al.2004 (16)	Non bleached group	Immediate restoration group after bleaching Bleaching then applied 10% sodium ascorbate immediately for 3 hours before restoration group Delayed restoration group for 1 week after bleaching	The immediate restoration after nonvital bleaching by 10% carbamide peroxide will increase the microleakage of the composite, whereas treatment with antioxidants after bleaching will prevent the microleakage of the composite and the delay restoration for 1 week after bleaching will decrease the microleakage of the composite but not remove it completely
Yazici et al. 2010 (25)	Non-bleached group with (Single bond; Adoper SE plus; One Coat bond; Adper Easy One; G-bond)	Bleached group with (Single bond; Adoper SE plus; One Coat bond; Adper Easy One; G-bond)	In comparison between control and intervention groups, the microleakage increases significantly only in Single bond and Adper Easy One bond when using home bleaching
Yu et al. 2010 (9)	Non-bleached group (without resin coating; with resin coating)	Bleached group (without resin coating; with resin coating)	There are no significant differences in microleakage among the control and intervention groups of composite resin

* Quartz-tungsten halogen (QTH), light emitting diode (LED), plasma arc (PAC), Crest regular Cavity Protection (CCP)

Table 4 Risk of bias assessment of included studies.

Author	Randomization	Sample size calculation	Comparable groups	Detailed information regarding measurements	Proper statistical analysis	Manufacturer's instructions	Single Operator operator	blinded	Risk of bias
BEKTAS et al. 2012 (26)	Yes	No	Yes	Yes	Yes	Yes	No	No	Medium
Bulucu et al. 2008 (7)	Yes	No	Yes	Yes	Yes	Yes	No	No	Medium
Demarco et al. 2001 (23)	Yes	No	Yes	Yes	Yes	Yes	No	No	Medium
Han et al. 2014 (15)	Yes	No	Yes	Yes	Yes	Yes	No	No	Medium
Hashemikamangar et al. 2014 (27)	Yes	No	Yes	Yes	Yes	Yes	No	No	Medium
Iovan et al. 2018 (28)	Yes	No	Yes	Yes	Yes	No	No	No	Medium
Khoroushi et al. 2009 (29)	Yes	No	Yes	Yes	Yes	Yes	No	No	Medium
Klein Jr et al. 2018 (22)	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Low
Klukowska et al. 2008 (30)	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Low
Meshkinnejad et al. 2022 (24)	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Low
Moosavi et al. 2010 (21)	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Low
Moosavi et al. 2009 (31)	Yes	No	Yes	Yes	Yes	Yes	No	No	Medium
Mortazavi et al. 2011 (32)	Yes	No	Yes	Yes	Yes	Yes	No	No	Medium
Roubickova et al. 2013 (33)	Yes	No	Yes	Yes	Yes	Yes	No	No	Medium
Teixeira et al. 2003 (13)	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Low
Türkün et al.2004 (16)	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Low
Yazici et al. 2010 (25)	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Low
Yu et al. 2010 (9)	Yes	No	Yes	Yes	Yes	No	No	Yes	Medium

Discussion

This review is the first to present the data gathered from experimental in vitro studies that measure the microleakage resulting from the bleaching effect on composite restoration. The included studies utilized a range of bleaching materials and various composite types, including two types of cavities, class V and access cavities. Additionally, there were variations in the first procedure performed on the study samples and differences in the microleakage scoring systems employed across studies. Given the methodological variability and high heterogeneity, conducting a meta-analysis of the included articles is challenging.

Our study consists of two major groups: the pre-restorative bleaching group and the post-restorative one. Among the eight articles in the pre-restorative bleaching group, all demonstrate microleakage in the bleached groups that were not treated with antioxidants or allowed a sufficient time elapsed period (7, 13, 15, 16, 21, 23-25). These articles reveal a significant difference between the control and bleached groups, confirming the influence of pre-restorative bleaching techniques on composite resin restoration. However, it is important to note that Yazici et al. (25) reported significant differences between the control and bleached groups for only two out of the five tested bond types, as shown in Table 3.

On the other hand, among the articles on postoperative bleaching (9, 22, 26-33), the results of the present studies exhibit significant variations. Some studies showed no significant difference between the control and intervention groups, regardless of the adhesive type used (22, 26, 28, 29). However, Mortazavi found no difference between the adhesive systems in the control and bleaching groups at the enamel margin, but a difference was observed at the gingival margin (32). Furthermore, certain studies demonstrated a difference between adhesive types, with the total etch bond type exhibiting less microleakage than self-etch (33). Additionally, one study reported significant differences between the control and bleached groups based on the type of composite used (31).

Nevertheless, some studies found no significant difference between adhesive systems, composite types, or bleaching methods. However, in these studies, using a resin coat or Crest Regular Cavity Protection (CCP) dentifrice may have contributed to these results (9, 27, 30). It should be noted that the main cause of these controversial results primarily stems from the significant differences in the experimental conditions across all studies in this group. The bleaching concentrations, composite types, and adhesive systems used varied considerably among the postoperative studies. Therefore, there is a need for future studies that closely replicate experimental conditions to demonstrate the influence of postoperative bleaching on microleakage accurately.

Among the 11 articles that examined microleakage in enamel and dentine, nine focused on post-restorative bleaching (9, 26-33), and 2 examined pre-restorative bleaching (7, 15). Certain studies (7, 26) demonstrated a significant difference in microleakage between the enamel and dentin margins of the composite. This difference can be attributed to various factors, such as lower mineral content, increased moisture, and a higher organic matrix in dentin, which are more susceptible to the effects of bleaching; when bleaching affects the organic and inorganic components of dentin, protein denaturation occurs, resulting in reduced resin bond strength. Consequently, microleakage tends to be higher in dentin than enamel (9, 27).

Conversely, some studies found no significant difference in microleakage between enamel and dentin margins of the composite(27-31). The remaining studies (9, 15, 32, 33) did not mention whether there was a significant difference between enamel and dentin. Based on these findings, future studies are needed to investigate further the significant differences in marginal integrity between enamel and dentin concerning the bleaching effect.

Several explanations have been proposed in the literature regarding the increased microleakage of resin composite after bleaching. This increase can be attributed to the oxidation reaction during the bleaching process. When hydrogen peroxide breaks down, it releases oxygen remnants and free radicals that penetrate the tooth surface. These agents convert large pigmented molecules into smaller ones. The presence of residual oxygen can hinder resin polymerization and even interfere with the curing process, compromising the composite restoration's adhesive properties (13, 15, 23).

On the other hand, in the context of postoperative bleaching, the exact explanation for the reduced marginal integrity is not yet clear. However, some authors suggest that when the bleaching agent penetrates deeply, it may create a gap between the tooth and the restoration interface. Over time, this interface may gradually expand, decreasing the adhesion quality and ultimately resulting in microleakage (22).

For the pre-restorative bleaching group, many authors have mentioned that the effect of the bleaching process is reversible and time-dependent. Therefore, waiting a specific time before applying the restoration can prevent microleakage and improve the sealing ability at the composite-tooth interface after the bleaching procedure (15, 17). It has been reported in several studies that immediate restoration following bleaching results in a high rate of microleakage (13, 15, 16, 23, 24). This is attributed to the presence of free radicals and oxygen introduced by the bleaching agent, as mentioned previously (13, 15, 16). Consequently, researchers have focused on delaying the composite restoration placement for specific time intervals after bleaching to dissipate the bleaching effect (13, 15, 16, 24).

One study indicates that a one-week duration between bleaching and composite application has minimal impact on improving sealing ability and reducing microleakage (16). However, other studies demonstrate that waiting for two weeks after bleaching leads to a significant reduction in microleakage compared to immediate restoration. This reduction is attributed to the sufficient time for releasing oxygen and the prevention of microleakage (13, 24). On the other hand, some studies show that delaying composite restoration for three weeks after bleaching does not result in a significant difference in microleakage formation compared to immediately restored teeth (15). Although the elapsed time approach may contribute to reducing microleakage and improving sealing ability, it is considered time-consuming for both patients and clinicians (2, 15). As a result, researchers have explored alternative methods to overcome the drawbacks of the elapsed time approach, leading to the advocacy of using antioxidants as a quicker alternative (2, 15).

Several antioxidants have been suggested in the literature, including sodium ascorbate, sodium bicarbonate, vitamin E, ascorbic acid, catalase, ethanol, glutathione, and acetone. These antioxidants aim to remove residual oxygen and reduce free radical components on the tooth surface after bleaching, thereby reducing microleakage (2, 15). Some of these antioxidants are biocompatible and nontoxic with no clinical hazards (16, 21, 24). For example, vitamin E is a useful antioxidant due to its alcohol content, which increases the bonding strength of the composite to the enamel surface. On the other hand, ascorbic acid is deemed unsuitable for clinical use due to its low pH of 1.8 and the difficulty in storing it for long periods due to oxidation of its components (15).

Studies have demonstrated that treating the tooth surface with antioxidants immediately before composite restoration effectively reduces microleakage (15, 16, 21, 24). This indicates that antioxidants can counteract the adverse effects of bleaching on tooth structure. The importance of antioxidants becomes particularly evident in intracoronary bleaching, where immediate restoration after the whitening process is considered convenient and time-saving for patients; in studies focusing on antioxidants, Moosavi and Turkun demonstrated that the application of sodium ascorbate for 3 hours resulted in a significant reduction in microleakage when compared to the immediately restored group without the use of antioxidants (16, 21). On the other hand, Meshkinnejad et al. also demonstrated that using sodium ascorbate, ascorbic acid, and vitamin C for just 10 minutes significantly reduced microleakage compared to the immediately restored group without antioxidants (24). Conversely, the 1-minute application of sodium ascorbate showed no significant difference from the immediately restored group without antioxidants. However, when sodium ascorbate was applied for 1 minute with a surfactant like Tween 80 or catalase, it showed a significant difference from the immediately restored group without antioxidants in the same study (15). These results highlight the critical role of antioxidants in reducing microleakage in the pre-restorative bleaching group. However, additional studies are needed to determine the minimum and optimal duration of antioxidant application.

The included studies assessed the marginal integrity using a dye penetration technique, a cost-effective, easily applied, and commonly used method for evaluating microleakage (34). Four different dyes were employed in these studies: methylene blue, basic fusion, Rhodamine B solution, and India ink. However, some authors have indicated certain disadvantages associated with these dyes. One concern is the lower molecular weight of several dye types compared to bacteria, which can result in less objective results. This discrepancy arises because the behavior of dyes does not necessarily mirror that of bacteria in the oral cavity, where bacteria do not infiltrate in the same manner as dyes (23, 35).

Among the included studies, a longitudinal sectioning approach was utilized to measure the extent of dye penetration. However, this method may not provide accurate results since it does not account for the overall distribution of microleakage. We may overcome this limitation by employing a multiple-sectioning method and obtain more precise results (9, 16).

Next, the microleakage score, which estimates the depth of dye penetration between the cavity walls and the restorations under microscopic examination, varied significantly across studies. Twelve studies employed a 0-3 rating system (9, 15, 16, 21, 22, 24, 27-29, 31-33), three studies used a 0-2 rating system (7, 13, 23), and three studies adopted a 0-4 rating system (25, 26, 30). The score results represent ordinal data and are not expressed numerically in all studies; instead, they are often presented as median or sum ranks. Consequently, it is not possible to directly compare studies using statistical analysis. To facilitate future comparisons, it is advisable to standardize the scoring system or employ a method that provides continuous data for measuring dye penetration, ensuring more accurate results and minimizing the subjectivity associated with ordinal data (15). Furthermore, using a dye type that closely matches the molecular weight of bacteria is preferable, as this would yield more precise outcomes.

Conclusion

Despite the heterogeneity observed, our study showed that the pre-restorative bleaching group exhibits microleakage in composite restorations. However, the application of an antioxidant or a waiting period after the bleaching technique can potentially mitigate the occurrence of microleakage. Conversely, in the post-restorative bleaching group, the impact of bleaching techniques on the microleakage of composite restorations is minimal. Microleakage can be prevented by employing a high-quality composite material and an adhesive system with strong sealing resistance. Findings from this review could guide clinicians in making necessary precautionary techniques when bleaching on composite restorations.

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Competing interests

The authors declare that they have no competing interests.

Ethical Clearance

Not Applicable

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