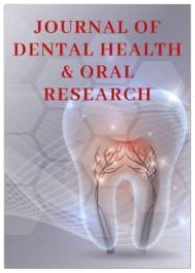

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Review Article

Does the Consumption of Pigmented Beverages and Foods During In-Office Bleaching Compromise Whitening Outcomes? A Systematic Review and Meta-Analysis

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Abstract

This study aimed to perform a systematic review and meta-analysis to evaluate whether pigment consumption influences the effectiveness of Dental Bleaching (DB) and whether diet affects tooth sensitivity. Following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, clinical trials were searched in PubMed, Embase, Web of Science, Cochrane, Scopus and OpenGrey. The PECO/PICO strategy considered individuals undergoing DB, those exposed to a pigment-rich diet, those with dietary restrictions and bleaching effectiveness. Risk of bias was assessed with ROBINS-I and RoB 2 and data were extracted by two independent reviewers. The certainty of evidence was graded using GRADE and quantitative synthesis was performed through meta-analysis. Eight studies were included; five were rated as low risk of bias and three as unclear. Meta-analysis showed no significant difference in color change (ΔE) between groups with and without pigment restrictions at any time point ($p \geq 0.24$). Similarly, no significant differences in tooth sensitivity were observed between groups ($p \geq 0.33$). Study heterogeneity was low ($I^2 = 0\text{-}68\%$) and the certainty of evidence was rated as low or very low for both outcomes. The findings suggest that consuming dietary pigments during bleaching does not compromise whitening effectiveness or increase tooth sensitivity. However, due to the limited number of studies and the potential risk of bias, definitive conclusions cannot yet be drawn.

Keywords: Tooth Bleaching; Dental Bleaching; Tooth Bleaching Agents; Tooth Stain; Pigmenting Liquids; Coloring Agents

Introduction

In contemporary dentistry, esthetic treatments play an important role, with tooth color being one of the main factors influencing the appearance of the smile [1]. Whiter teeth are often associated by society with health and beauty, which has contributed to the growing popularity and demand for brighter smiles [2]. Among the various approaches available to correct tooth discoloration, Dental Bleaching (DB) stands out as the most widely used technique due to its safety, minimally invasive nature, effectiveness and high success rate [3,4]. However, despite its effectiveness, DB can cause temporary alterations in enamel, such as increased permeability and superficial demineralization [5,6].

Some studies have reported that freshly bleached enamel may be more susceptible to staining immediately after the bleaching process and that certain dietary components could compromise bleaching outcomes [6,7]. To prevent the incorporation of

pigments into the newly bleached tooth structure, it is common for clinicians to recommend that patients avoid pigmented beverages and foods a so-called "white diet" during bleaching treatment [8]. Another factor to be considered is diet acidity. Acidic beverages (such as soft drinks) have been shown to affect the intensity of Tooth Sensitivity (TS) in patients who frequently consume them during bleaching [9].

A systematic review by Soares, et al., based on *in-vitro* studies suggested that coffee consumption does not appear to influence bleaching effectiveness, although red wine and soft drinks could potentially alter pigmentation and affect tooth color change [10]. Contrary to the widespread belief that adherence to a “white diet” is necessary, some recent clinical publications and systematic reviews have indicated that color change and bleaching speed seem to be independent of dietary restrictions [11-15]. Nonetheless, questions remain as to whether the consumption of pigmented foods and beverages during bleaching treatment truly compromises bleaching outcomes and whether dietary factors may also influence clinically relevant outcomes, such as dental sensitivity.

Many people consume coffee, tea, red wine, soft drinks and dark fruits as part of their daily routine and completely prohibiting these foods and beverages for esthetic purposes would be impractical. It remains a challenge for dentists to properly advise their patients on the extent to which diet may influence bleaching, as literature provides conflicting information. Therefore, the aim of the present study was to conduct a systematic review of the literature to evaluate the influence of pigment consumption on the effectiveness of DB, as well as whether diet affects patients’ sensitivity to the procedure.

Materials and Methods

Protocol and Registration

The study protocol was registered in the Prospective Register of Systematic Reviews (PROSPERO; CRD42022359009) and followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [16].

Search Strategy

Six databases namely PubMed, Embase, Web of Science, CENTRAL (Cochrane Library), Scopus and OpenGrey (source of grey literature) were searched on November 12, 2024 and updated on June 22, 2025. MeSH terms and keywords were selected and adapted for each database (Table 1). The search strategy aimed to identify all relevant published articles without restrictions on language or publication date.

Databases	Search Strategy
PubMed	("Tooth Bleaching" OR "Teeth Bleaching" OR "Tooth Whitening" OR "Teeth Whitening" OR "Tooth Bleaching Agents" OR "Teeth Bleaching Agents" OR "Tooth Whitening Agents" OR "Teeth Whitening Agents") AND ("Diet" OR "Diets" OR "Food" OR "Foods" OR "Food and Beverages" OR "Food And Beverage" OR "Food Coloring Agents" OR "Food Colorants" OR "Pigmentation" OR "Coffee" OR "Coffea" OR "Wine" OR "Tea" OR "Black Tea" OR "Black Teas" OR "Green Tea" OR "Green Teas" OR "Caffeine")
Embase	('tooth bleaching':kw OR 'teeth bleaching':kw OR 'tooth whitening':kw OR 'teeth whitening':kw OR 'tooth bleaching agents':kw OR 'teeth bleaching agents':kw OR 'tooth whitening agents':kw OR 'teeth whitening agents':kw OR 'tooth bleaching':ti OR 'teeth bleaching':ti OR 'tooth whitening':ti OR 'teeth whitening':ti OR 'tooth bleaching agents':ti OR 'teeth bleaching agents':ti OR 'tooth whitening agents':ti OR 'teeth whitening agents':ti OR 'tooth bleaching':ab OR 'teeth bleaching':ab OR 'tooth whitening':ab OR 'teeth whitening':ab OR 'tooth bleaching agents':ab OR 'teeth bleaching agents':ab OR 'tooth whitening agents':ab OR 'teeth whitening agents':ab) AND ('diet':kw OR 'diets':kw OR 'food':kw OR 'foods':kw OR 'food and beverages':kw OR 'food and beverage':kw OR 'food coloring agents':kw OR 'food colorants':kw OR 'pigmentation':kw OR 'coffee':kw OR 'coffea':kw OR 'wine':kw OR 'tea':kw OR 'black tea':kw OR 'black teas':kw OR 'green tea':kw OR 'green teas':kw OR 'caffeine':kw OR 'diet':ti OR 'diets':ti OR 'food':ti OR 'foods':ti OR 'food and beverages':ti OR 'food and beverage':ti OR 'food coloring agents':ti OR 'food colorants':ti OR 'pigmentation':ti OR 'coffee':ti OR 'coffea':ti OR 'wine':ti OR 'tea':ti OR 'black tea':ti OR 'black teas':ti OR 'green tea':ti OR 'green teas':ti

	OR 'caffeine':ti OR 'diet':ab OR 'diets':ab OR 'food':ab OR 'foods':ab OR 'food and beverages':ab OR 'food and beverage':ab OR 'food coloring agents':ab OR 'food colorants':ab OR 'pigmentation':ab OR 'coffee':ab OR 'coffea':ab OR 'wine':ab OR 'tea':ab OR 'black tea':ab OR 'black teas':ab OR 'green tea':ab OR 'green teas':ab OR 'caffeine':ab)
Web of Science	TS=("Tooth Bleaching" OR "Teeth Bleaching" OR "Tooth Whitening" OR "Teeth Whitening" OR "Tooth Bleaching Agents" OR "Teeth Bleaching Agents" OR "Tooth Whitening Agents" OR "Teeth Whitening Agents") AND TS=("Diet" OR "Diets" OR "Food" OR "Foods" OR "Food and Beverages" OR "Food And Beverage" OR "Food Coloring Agents" OR "Food Colorants" OR "Pigmentation" OR "Coffee" OR "Coffea" OR "Wine" OR "Tea" OR "Black Tea" OR "Black Teas" OR "Green Tea" OR "Green Teas" OR "Caffeine")
Cochrane	"Tooth Bleaching" OR "Teeth Bleaching" OR "Tooth Whitening" OR "Teeth Whitening" OR "Tooth Bleaching Agents" OR "Teeth Bleaching Agents" OR "Tooth Whitening Agents" OR "Teeth Whitening Agents") AND ("Diet" OR "Diets" OR "Food" OR "Foods" OR "Food and Beverages" OR "Food And Beverage" OR "Food Coloring Agents" OR "Food Colorants" OR "Pigmentation" OR "Coffee" OR "Coffea" OR "Wine" OR "Tea" OR "Black Tea" OR "Black Teas" OR "Green Tea" OR "Green Teas" OR "Caffeine") in Title Abstract Keyword
Scopus	(TITLE("Tooth Bleaching" OR "Teeth Bleaching" OR "Tooth Whitening" OR "Teeth Whitening" OR "Tooth Bleaching Agents" OR "Teeth Bleaching Agents" OR "Tooth Whitening Agents" OR "Teeth Whitening Agents") OR ABS("Tooth Bleaching" OR "Teeth Bleaching" OR "Tooth Whitening" OR "Teeth Whitening" OR "Tooth Bleaching Agents" OR "Teeth Bleaching Agents" OR "Tooth Whitening Agents" OR "Teeth Whitening Agents") OR KEY("Tooth Bleaching" OR "Teeth Bleaching" OR "Tooth Whitening" OR "Teeth Whitening" OR "Tooth Bleaching Agents" OR "Teeth Bleaching Agents" OR "Tooth Whitening Agents" OR "Teeth Whitening Agents")) AND (TITLE("Diet" OR "Diets" OR "Food" OR "Foods" OR "Food and Beverages" OR "Food And Beverage" OR "Food Coloring Agents" OR "Food Colorants" OR "Pigmentation" OR "Coffee" OR "Coffea" OR "Wine" OR "Tea" OR "Black Tea" OR "Black Teas" OR "Green Tea" OR "Green Teas" OR "Caffeine") OR ABS("Diet" OR "Diets" OR "Food" OR "Foods" OR "Food and Beverages" OR "Food And Beverage" OR "Food Coloring Agents" OR "Food Colorants" OR "Pigmentation" OR "Coffee" OR "Coffea" OR "Wine" OR "Tea" OR "Black Tea" OR "Black Teas" OR "Green Tea" OR "Green Teas" OR "Caffeine") OR KEY("Diet" OR "Diets" OR "Food" OR "Foods" OR "Food and Beverages" OR "Food And Beverage" OR "Food Coloring Agents" OR "Food Colorants" OR "Pigmentation" OR "Coffee" OR "Coffea" OR "Wine" OR "Tea" OR "Black Tea" OR "Black Teas" OR "Green Tea" OR "Green Teas" OR "Caffeine"))
OpenGrey	("Tooth Bleaching" OR "Teeth Bleaching" OR "Tooth Whitening" OR "Teeth Whitening" OR "Tooth Bleaching Agents" OR "Teeth Bleaching Agents" OR "Tooth Whitening Agents" OR "Teeth Whitening Agents") AND ("Diet" OR "Diets" OR "Food" OR "Foods" OR "Food and Beverages" OR "Food And Beverage" OR "Food Coloring Agents" OR "Food Colorants" OR "Pigmentation" OR "Coffee" OR "Coffea" OR "Wine" OR "Tea" OR "Black Tea" OR "Black Teas" OR "Green Tea" OR "Green Teas" OR "Caffeine")

Table 1: Search strategies appropriately defined for each database.

Eligibility Criteria and Study Selection Process

The inclusion criteria were based on the PECO or PICO strategy [17]. Two researchers (EVT and BLO) independently screened the titles and abstracts of studies identified in the electronic databases. Articles retrieved from multiple databases were considered only once. Data from each database were exported to the reference management software EndNote (Clarivate Analytics, Philadelphia, USA). Duplicates were removed in a two-step process. In the first step, a specific EndNote tool was used to remove duplicates. However, this tool could not eliminate all duplicates due to differences in the indexing processes across databases. In the second step, articles were sorted alphabetically by title and duplicates were manually identified and removed. Any disagreements between researchers were resolved through discussion and consensus, and, if necessary, a third researcher (CMA) was consulted. For studies that appeared to meet the inclusion criteria or when title and abstract data were insufficient to make an informed decision, full-text articles were retrieved and reviewed. Only studies meeting the following criteria were included:

- Participants: Adult patients (at least 18 years old) undergoing dental bleaching with hydrogen peroxide or carbamide peroxide to improve tooth shade. Participants with any dental malformations, fluorosis, tetracycline stains, caries and restored or endodontically treated teeth were excluded
- Intervention/Exposure: Individuals consuming pigmented foods or beverages during bleaching treatment
- Comparison: Individuals not consuming pigmented foods or beverages during bleaching treatment
- Outcomes: Changes in color measured in Shade Guide Units (ΔSGU) and CIELab parameters (ΔE) were assessed as primary outcomes. For secondary outcomes, both the risk and intensity of Tooth Sensitivity (TS) during bleaching were assessed using the Visual Analog Scale (VAS) and Numerical Rating Scale (NRS). No follow-up period restrictions were imposed
- Study design: Randomized and non-randomized clinical trials

A manual search of the reference lists of included studies was also performed to identify additional potentially relevant articles. Two researchers (EVT and BLO) independently screened all references from these studies.

Data Extraction

Data were extracted from eligible studies by two independent reviewers (EVT and BLO). Any disagreements were resolved by discussion or consensus involving a third reviewer (CMA). Information collected included: author, publication year, study design, sample size, method of color assessment, bleaching protocol (concentration and product of bleaching gel; application time, interval between applications and total number of sessions/weeks), tested staining agents, staining protocol used, dietary restrictions, follow-up period after bleaching protocol and outcomes. In cases of missing data, attempts were made to contact the corresponding author by email weekly for up to four weeks to clarify missing information.

Risk of Bias and Certainty of Evidence Assessment

The full texts of articles meeting eligibility criteria were comprehensively and independently assessed by two researchers (EVT and BLO) for methodological risk of bias using the Cochrane RoB 2 tool for randomized clinical trials and the ROBINS-I tool for non-randomized studies [18,19]. Any disagreements were resolved through discussion and consensus; if necessary, a third researcher (CMA) was consulted.

For the Cochrane RoB 2 tool, the overall risk of bias was classified as low, unclear or high based on six key domains: bias from the randomization process; bias due to deviations from intended interventions; bias due to missing outcome data; bias in outcome measurement; bias in selection of the reported result; and overall bias. For all studies classified as "unclear" in any key domain, the article authors were contacted for additional information. For the ROBINS-I tool, methodological risk of bias was assessed across seven domains: confounding, participant selection, classification of interventions, deviations from intended interventions, missing data, outcome measurement and selection of the reported result. Each domain was rated as "low," "moderate," "serious," "critical," or "no information," resulting in an overall risk of bias judgment.

Certainty of evidence (certainty in effect estimates) was determined by two independent reviewers (EVT and BLO) for color change and tooth sensitivity outcomes using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach [20]. Any disagreements were resolved by discussion or consensus involving a third reviewer (AMS). According to the GRADE approach, included clinical studies initially provide high-quality evidence; however, certainty can be downgraded to moderate, low or very low if serious or very serious issues related to risk of bias, imprecision, inconsistency, indirectness or publication bias are identified [21].

Meta-Analysis

Meta-analyses were performed using RevMan 5 statistical software (Review Manager, version 5.4). Since color change data were measured using different scales, only studies that used the CIELab* system (ΔE) were included in quantitative analyses. For continuous outcomes, Standardized Mean Difference (SMD) was used and meta-analyses were conducted at six different time points: during bleaching at weeks 1, 2 and 3 and after bleaching at 1 week, 2 weeks and 1 month. Subgroup analyses were conducted to explore the impact of follow-up time on color change outcomes. For the secondary outcome, tooth sensitivity, self-reported pain data measured using the VAS were also analyzed at six different time points.

Only clinically and methodologically homogeneous studies were included in the meta-analysis. Different dietary pigments and the varying concentrations of the two bleaching agents evaluated (hydrogen peroxide and carbamide peroxide) were combined in the analyses, since the main goal was to assess the effect of diet on color change and tooth sensitivity regardless of the type of pigment or bleaching agent used. Additionally, a combined approach was necessary due to the limited number of available clinical studies and insufficient data for subgroup analyses by pigment type, bleaching gel or concentration.

Meta-analyses were conducted using a random-effects model, applying the inverse variance method to calculate effect measures and corresponding 95% confidence intervals. Statistical heterogeneity was assessed using the I^2 statistic. Effect sizes of individual studies and pooled effects were presented in forest plots. Publication bias assessment through funnel plots was not performed, as the number of included studies was fewer than 10, which would compromise the statistical power of this analysis, as recommended by PRISMA guidelines [16].

Results

Study Selection

The initial search across all sources yielded 801 records (from databases and citation searches). Of these, 293 duplicate studies were removed using the EndNote reference management software and an additional 112 duplicates were manually excluded. Another 388 studies were excluded after screening titles and abstracts. Nine potentially relevant studies were retrieved and analyzed in full text. Of these, eight met the inclusion criteria and were included in both the qualitative and quantitative synthesis (Fig. 1).

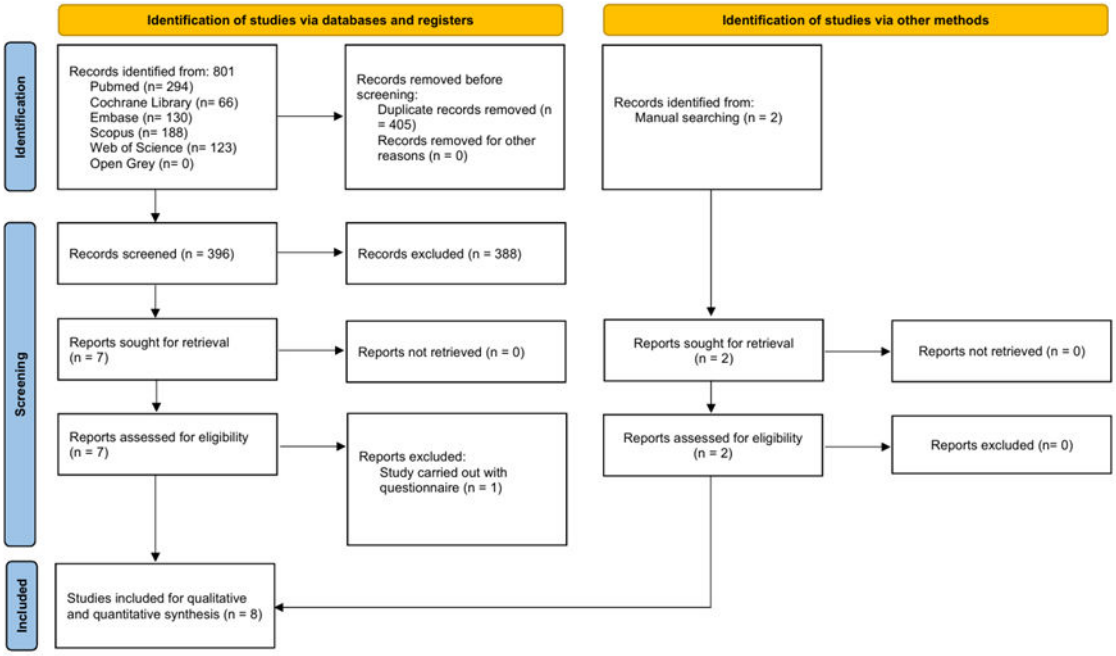

Figure 1: Flowchart showing the results of manual searches and database searches.

Characteristics of Included Studies

The characteristics of the included studies are summarized in Table 2. The number of patients enrolled in these clinical trials ranged from 40 to 80 participants. All included studies primarily aimed to evaluate the effect of dietary pigments on Dental Bleaching (DB) outcomes [9,11-13,22-25].

In addition to pigments commonly present in the diet, most studies also implemented daily mouth rinses with staining substances, except for the study by Biz [25]. In the studies by Rezende, et al. and Chen, et al., participants performed coffee rinses four times a day for four weeks [11,22]. Chen, et al., also assessed the effect of ready-to-drink tea pigments. Participants in the studies by De Souza, et al. and Menezes, et al., performed rinses with red wine, whereas Hass, et al., combined an unrestricted diet with four daily rinses using cola-based soft drinks [9,11-13]. The studies by Dos Santos, et al. and Campos, evaluated the

effect of three daily rinses with grape nectar and grape juice, respectively [21,24]. Biz, only investigated the effect of pigments typically consumed as part of a habitual diet, without additional rinses [25].

Regarding the bleaching protocol, four studies investigated supervised at-home bleaching, two evaluated in-office bleaching and two assessed both at-home and in-office bleaching. Three different concentrations of carbamide peroxide (7.5%, 10% and 16%) and hydrogen peroxide (35%, 37% and 40%) were used across the included studies. All studies used the VITA Easyshade spectrophotometer (VITA Zahnfabrik, Bad Säckingen, Germany) for objective color assessment. Three studies performed subjective color evaluation using the Vita Classical Shade Guide (VITA Zahnfabrik, Bad Säckingen, Germany) [9,13,20]. The study by Hass, et al., also used the Vita Bleachedguide 3D-Master (VITA Zahnfabrik, Bad Säckingen, Germany) for subjective color analysis [9]. In addition to assessing treatment effectiveness, the included studies asked participants about the occurrence of tooth sensitivity during and immediately after bleaching product use. Sensitivity was measured using a Visual Analog Scale (VAS), completed by the participants themselves. The studies by Rezende, et al., Hass, et al., Chen, et al. and Menezes, et al., also used a five-point Numerical Rating Scale (NRS) with the following pain criteria: 0 = none, 1 = mild, 2 = moderate, 3 = considerable and 4 = severe [9,11,13,22].

Author/Country	Study Design	Staining Agents	Groups (Sample Size)	Staining Protocol	Bleaching Agent	Bleaching Protocol	Color Measurement	Color Change	Dental Sensitivity	Follow-Up
Rezende, 2013. Brazil [22]	Controlled clinical trial	Coffee	Didn't drink coffee (n = 20) and drank black coffee at least twice a day (n = 20)	Coffee intake (2 to 3 cups/day) combined with black coffee mouth rinses for 30 seconds, 4 times/day.	16% carbamide peroxide (Whiteness Perfect, FGM Dental Products, Joinville, Brazil)	3 hours/day for 3 weeks	Vita Classic Shade Guide and Spectrophotometer (Vita Easyshade)	Coffee consumption did not interfere with the effectiveness of bleaching ($p > 0.05$).	Coffee consumption did not affect the risk and intensity of sensitivity ($p > 0.05$).	Not evaluated
Campos, 2018. Brazil [23]	Randomized controlled clinical trial	Grape juice	Restricted diet (n = 25) and non-restricted diet with grape juice mouth rinses (n = 22)	Restricted diet and non-restricted diet combined with 50 ml grape juice mouth rinses for 30 seconds, 3 times/day.	7.5% hydrogen peroxide (Pola Day); 10% carbamide peroxide (WhiteGold Home); 35% hydrogen peroxide (Whiteness HP AutoMix); 35% hydrogen peroxide (WhiteGold Office).	3 bleaching sessions; 45 minutes/day for 21 days	Spectrophotometer (Vita Easyshade)	Exposure to grape juice did not influence the bleaching results, regardless of the bleaching technique ($p > 0.05$).	The relative risk showed a significant association between exposure to grape juice and the occurrence of dental sensitivity for in-office bleaching. No significant association was observed between exposure to grape juice and the occurrence of dental sensitivity	Not evaluated

									for at-home bleaching.	
Dos Santos, 2019. Brazil [24]	Randomized controlled clinical trial	Grape nectar	Bleaching and restricted diet (n = 10); bleaching without restricted diet and use of staining solution (n = 10); control group with brushing using conventional toothpaste without restricted diet (n = 10); brushing with "whitening" toothpaste with restricted diet (n = 10); and brushing with "whitening" toothpaste without restricted diet and use of staining solution (n = 10).	Restricted diet and unrestricted diet combined with 3 mouth rinses/day for 30 seconds with grape nectar.	10% carbamide peroxide (Whitenes s Perfect/ FGM, Joinville, SC, Brazil)	8 hours/day for 15 days	Spectrophotometer (Vita Easyshade)	Contact with the staining agent did not influence the bleaching results ($p > 0.05$).	There was no difference between the groups regarding sensitivity reports ($p > 0.05$).	Not evaluated
Hass, 2019. Brazil [9]	Controlled clinical trial	Coca-Cola	Restricted diet (n = 22) and mouth rinses with Coca-Cola after bleaching without dietary restrictions (n = 22).	Restricted diet and unrestricted diet combined with Coca-Cola mouth rinses for 30 seconds, 4 times/day.	35% hydrogen peroxide (Whitenes s HP Automixx 35, FGM Dental Products, Joinville, SC, Brazil)	2 bleaching sessions	Vita Classic Shade Guide and Bleachedguide 3D Spectrophotometer (Vita Easyshade)	Exposure to cola-based soft drink did not affect the bleaching efficacy ($p > 0.08$).	Significantly higher scores on the VAS and NRS were observed for the experimental group ($p < 0.05$).	Not evaluated

Chen, 2020. China [11]	Randomized controlled clinical trial	Coffee and Tea	Controle (n= 20), café (n= 21) e chá (n= 21).	Rinse with water, coffee or tea solutions for 30 seconds, 4 times/day, for 4 weeks	40% hydrogen peroxide (Opalescence BOOST, Ultradent)	2 bleaching sessions	Spectrophotometer (Vita Easyshade)	Exposure to coffee or tea during the bleaching treatment period did not affect the treatment efficacy ($p > 0.05$).	Exposure to staining beverages did not affect sensitivity ($p > 0.05$).	Exposure to coffee after the bleaching treatment affected the treatment efficacy ($p < 0.05$).
Biz, 2020. Brazil [25]	Controlled clinical trial	Restricted diet and non-restricted diet	Restricted diet (n = 24) and non-restricted diet (n = 22).	Those who reported consuming at least once a day any of the following foods: coffee, cola-based soft drinks, grape or orange juice, red wine, chimarrão and açaí, were assigned to the experimental group.	37% carbamide peroxide (Power Bleaching, BM4, Maringá, Brazil). 10% carbamide peroxide (Power Bleaching, BM4, Maringá, Brazil)	6 bleaching sessions; 2 hours/day for 6 weeks	Spectrophotometer (Vita Easyshade)	No differences were observed between the groups for the two tested techniques ($p > 0.05$).	There was no statistical difference between the mean sensitivity scores when comparing the groups with and without pigmentation in the diet ($p > 0.05$).	After 60 days of treatment, the result remained stable.
De Souza, 2022. Brazil [12]	Randomized controlled clinical trial	Wine	Restricted diet without wine (n = 15), unrestricted diet without wine (n = 15) and unrestricted diet supplemented with wine (n = 15)	Restricted diet, unrestricted diet and unrestricted diet with wine mouth rinses, 3 times/day, for 5 minutes, for 14 days.	16% carbamide peroxide (Magic White, Vigodent-Coltene, Altstätten, Switzerland)	4 hours/day for 14 days.	Spectrophotometer (Vita Easyshade)	Intake of staining agents and mouth rinses with red wine did not influence the final clinical outcome ($p = 0.228$).	There was no significant difference between the groups regarding postoperative sensitivity after 7 and 14 days of treatment ($p = 0.263$ and $p = 0.542$).	Not evaluated

Menezes, 2022. Brazil [13]	Controlled clinical trial	Wine	Control (n = 40) and experimental (n = 40)	Restricted diet and restricted diet with wine consumption (1 bottle/week) and wine mouth rinses for 30 seconds, 4 times/day.	10% carbamide peroxide (Whitenes s Perfect/ FGM, Joinville, SC, Brazil)	4 hours/day for 3 weeks.	Vita Classic Shade Guide and Spectrophotometer (Vita Easyshade)	Red wine consumption did not interfere with the bleaching efficacy ($p > 0.05$).	Red wine did not affect dental sensitivity ($p > 0.05$).	Not evaluated

Table 2: Summary of studies included in this systematic review.

Risk of Bias Assessment and Quality of Evidence

Among the non-randomized studies, all were classified as having a low risk of bias, although two presented a moderate risk in the domains of participant selection or outcome measurement (Fig. 2). Of the four randomized clinical trials analyzed, one was considered at low risk of bias, while the other three showed an unclear risk due to issues related to sample randomization and/or deviations from planned interventions (Fig. 3). None of the studies in either group were assessed as having a critical risk of bias.

The variability in follow-up periods across studies hindered the pooling of data for evidence quality assessment. As a result, the certainty of evidence was rated as "very low" or "low" for all outcomes evaluated, also reflecting methodological limitations and imprecision in effect estimates (Supplementary Material).

Figure 2: Results of the risk of bias assessment of the studies included in the systematic review according to the ROBINS-I tool.

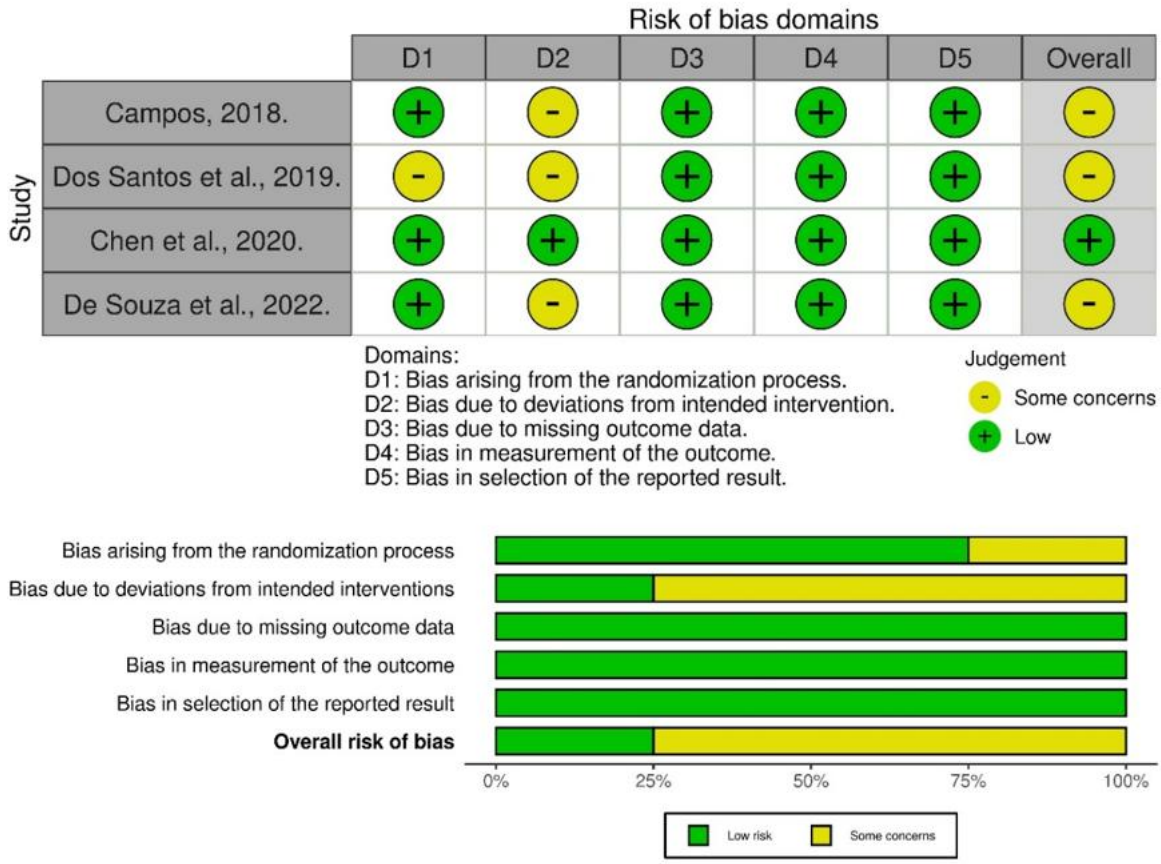

Figure 3: Results of the risk of bias assessment of the studies included in the systematic review according to the RoB 2 tool.

Individual Study Results Primary Outcomes

Rezende, et al., evaluated whether exposure to coffee during bleaching with 16% carbamide peroxide affects the degree of whitening [22]. Participants who did not drink coffee were assigned to the control group, while those who drank coffee at least twice daily were assigned to the experimental group. In the control group, foods containing dyes were restricted. For the experimental group, there were no dietary restrictions and participants were instructed to rinse with coffee for 30 seconds, four times daily. The results showed that bleaching was effective in both groups after three weeks, with no statistical difference in subjective and objective ΔSGU values ($p = 0.962$ and $p = 0.964$, respectively) or in ΔE values ($p = 0.934$).

Campos, evaluated the impact of grape juice consumption on the effectiveness of both at-home and in-office dental bleaching protocols, using different bleaching agents (10% carbamide peroxide, 7.5% hydrogen peroxide and 35% hydrogen peroxide with and without calcium) [23]. Participants in the experimental group rinsed with grape juice three times daily for 30 seconds over up to three weeks. The results showed that exposure to grape juice did not interfere with ΔE values, regardless of bleaching technique or agent used ($p > 0.05$).

Dos Santos, et al., investigated the impact of consuming foods with dyes during bleaching with 10% carbamide peroxide (used for 8 hours daily during sleep over 15 days) and the use of a "whitening" toothpaste (Luminous White Advanced, Colgate, Brazil) [24]. While the control group followed dietary restrictions, the experimental group had no restrictions and performed three daily rinses of 30 seconds with grape nectar, the first immediately after tray removal. There was no statistical difference ($p > 0.05$) in ΔE values between groups with and without dietary restrictions (ΔE = 4.28 and 4.42, respectively). The authors concluded that contact with the dye did not influence whitening outcomes and the whitening toothpaste was ineffective.

Hass, et al., conducted a study to assess whether exposure to cola-based soft drinks during bleaching with 35% hydrogen peroxide affects color change [9]. Participants who did not drink cola were assigned to the control group, while those who drank it at least twice daily were in the experimental group. The control group had dietary dye restrictions, while the experimental

group had no restrictions and rinsed with cola-based soft drinks for 30 seconds four times daily, including immediately after each bleaching session. Effective whitening was observed in both groups, with no statistical difference ($p > 0.08$) ($\Delta E = 8.9$ and 9; $\Delta SGU = 5.1$ and 4.9, respectively).

Chen, et al., conducted a randomized clinical trial assigning participants into three groups based on rinsing beverages during and after bleaching with 40% hydrogen peroxide: control group (tap water), coffee group and tea group [11]. Participants rinsed with their respective solutions for 30 seconds, four times daily for four weeks, with the first rinse immediately after the in-office bleaching procedure. No significant differences were observed in whiteness index (W), ΔE, Δa^* and Δb^* values among the three groups at any time point ($p > 0.05$). However, a follow-up assessment three weeks after bleaching suggested that coffee exposure may affect color stability.

Biz, clinically evaluated the effect of consuming foods with dyes on bleaching effectiveness, using 37% carbamide peroxide for the upper arch (in-office) and 10% for the lower arch (at-home) [25]. Forty-six participants were divided into a control group (without frequent pigment intake) and an experimental group (participants reporting at least daily consumption of coffee, cola, grape, orange, red wine, chimarrão or açaí). Color was measured at four time points (T0, T1, T2 and T3) and no statistical differences were observed between groups in color parameters (ΔE, ΔL^*, Δa^*, Δb^*). Both groups showed effective whitening, with average ΔE above 7. The authors concluded that pigment intake did not interfere with whitening intensity.

De Souza, et al., evaluated the influence of diet and red wine exposure on the speed of bleaching treatment with 16% carbamide peroxide [12]. Participants were divided into three groups: restricted diet without wine, free diet without wine and free diet supplemented with wine (rinses three times daily for five minutes). Diet and wine exposure did not influence clinical bleaching outcomes, as no statistical differences were found in ΔE, ΔL, Δa and Δb values among the groups. The study suggests that consuming food dyes during bleaching is not a decisive factor in clinical outcome.

Menezes, et al., investigated the effects of red wine exposure on the effectiveness of at-home bleaching with 10% carbamide peroxide [13]. Participants were divided into two groups: those who drank at least one bottle of red wine per week (experimental) and those who did not drink (control). The experimental group performed four daily rinses with red wine during bleaching. Effective whitening was observed in both groups, with no statistical differences ($p > 0.05$) ($\Delta E = 9.9$ and 8.9; $\Delta SGU = 7$ and 7, respectively).

The results from studies included in the qualitative synthesis for color change suggest that bleaching effectiveness is similar regardless of the consumption of cola-based soft drinks, coffee, tea, grape nectar and red wine or adherence to a restricted diet.

Individual Study Results Secondary Outcomes

Rezende, et al., evaluated whether coffee exposure during bleaching with 16% carbamide peroxide affected absolute risk and intensity of tooth sensitivity. Patients recorded their sensitivity using NRS and VAS [22]. The absolute risk of tooth sensitivity was 55% for the control group (95% CI: 34.2%-74.2%) and 60% for the experimental group (95% CI: 38.7%-78.2%). Sensitivity intensity was also similar between groups ($p=0.529$ for NRS; $p=0.258$ for VAS). About 57% of participants reported mild sensitivity.

Campos, assessed the impact of grape juice consumption on tooth sensitivity during in-office and at-home bleaching [23]. For in-office bleaching, absolute risks were 57.9% (control, 95% CI: 42.1-72.1%) and 84.2% (experimental, 95% CI: 69.5-92.5%), with a relative risk of 0.68 (95% CI: 0.50-0.93), indicating significantly higher sensitivity in the grape juice group ($p=0.011$). For at-home bleaching, absolute risks were 63.2% (control) and 71.1% (experimental), with relative risk 0.89 (95% CI: 0.65-1.22), $p=0.464$, showing no statistical difference. Dos Santos, et al., examined the impact of consuming foods with dyes and daily grape nectar rinses during bleaching with 10% carbamide peroxide [24]. Patients self-reported sensitivity using VAS and no differences were observed between groups ($p > 0.05$). Hass, et al., assessed whether exposure to cola-based soft drinks during bleaching with 35% hydrogen peroxide affected absolute risk and intensity of tooth sensitivity, recorded via NRS and VAS. Absolute risks were 32% (control, 95% CI: 16-52) and 27% (experimental, 95% CI: 13-48), with no significant difference (risk ratio: 0.8, 95% CI: 0.34-2.14, $p=0.74$) [9]. Sensitivity intensity was significantly higher after one hour of bleaching in the experimental group ($p<0.05$).

Chen, et al., randomized participants into three groups (tap water, coffee, tea) during and after bleaching with 40% hydrogen peroxide [11]. Sensitivity intensity was assessed using NRS and VAS at different time points. No significant differences were observed among groups at any evaluation ($p>0.05$). Median sensitivity during and up to one hour after bleaching ranged from 3-5 on VAS and 1-2 on NRS (mild to moderate).

Biz, assessed the influence of consuming foods with dyes on tooth sensitivity during in-office and at-home bleaching [25]. No significant differences were found between control and experimental groups for either bleaching technique ($p=0.50$ and $p=0.81$). Comparing techniques, regardless of diet, mean sensitivity was higher for at-home bleaching (1.68 ± 1.55) than in-office (0.86 ± 1.11), $p<0.01$, suggesting technique impacts sensitivity more than diet.

De Souza, et al., evaluated diet and red wine exposure during bleaching with 16% carbamide peroxide. Participants rated sensitivity on VAS [12]. Sensitivity was higher in the group with diet plus wine and lower in the free diet without wine group, but differences were not statistically significant at any time.

Menezes, et al., assessed whether red wine exposure during at-home bleaching with 10% carbamide peroxide affected absolute risk and intensity of tooth sensitivity, recorded daily via NRS and VAS [13]. Over 92% of participants in both groups experienced sensitivity at least once, with no significant differences between groups ($p>0.05$). Sensitivity intensity was similar across groups at all time points ($p>0.05$). The qualitative synthesis for tooth sensitivity during bleaching suggests that diet does not influence the risk or intensity of reported sensitivity.

Meta-Analysis

To include all studies, data originally reported as medians and interquartile ranges were converted to means and standard deviations. Sensitivity analysis excluding these transformed data showed consistent effect directions, supporting robustness. Regarding color change (Fig. 4), no significant differences were found between groups at any time point ($p\geq0.24$). Study heterogeneity was low to moderate and subgroup analysis did not show a differential effect of diet over time ($p=0.90$; $I^2=0\%$).

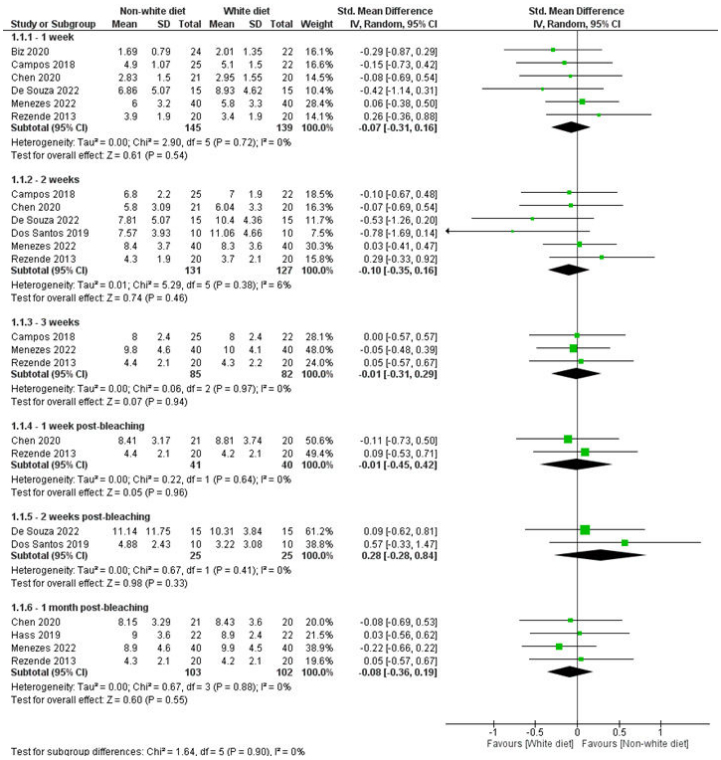

Figure 4: Forest plot of the meta-analysis on color change at different follow-up points during and after tooth bleaching, comparing groups with and without a white diet.

Regarding dental sensitivity (Fig. 5), none of the analyses showed a statistically significant difference between the groups who followed a white diet and those who did not ($p \geq 0.33$). Heterogeneity among the studies was low ($I^2 = 0\%$) in most subgroups,

except for the 1-hour analysis ($I^2 = 68\%$). The pooled effects demonstrated that diet did not influence the intensity of sensitivity reported by patients.

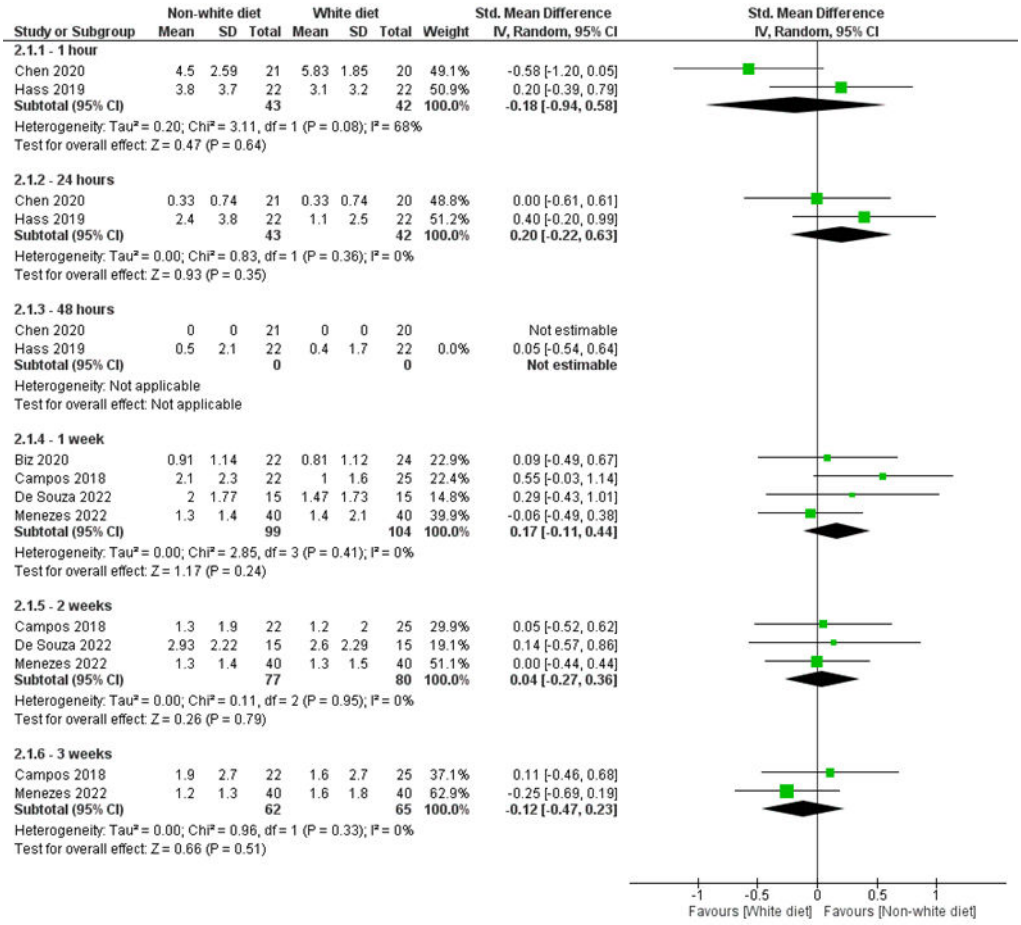

Figure 5: Forest plot of the meta-analysis on dental sensitivity at different follow-up points during and after tooth bleaching, comparing groups with and without a white diet.

Discussion

Laboratory studies indicate that bleaching agents can cause changes to the enamel surface due to their mild acidity and demineralizing potential, which could increase the retention of pigments in the enamel [7,26]. However, based on the findings of this systematic review, these possible alterations promoted by bleaching agents do not seem to have significant clinical relevance regarding dental staining. It is presumed that saliva plays an essential role in reversing the structural changes caused by bleaching agents [22]. Moreover, in most laboratory studies, the dental structure is exposed to conditions that are more critical and aggressive than those encountered in the oral environment [24]. The results obtained in this review indicate that bleaching is effective regardless of the consumption of cola-based soft drinks, coffee, tea, grape nectar or red wine or adherence to a restrictive diet [9,11-13,22,24]. Furthermore, the treatment's effectiveness did not depend on the technique employed (in-office or at-home bleaching), the concentration of the bleaching gel (10% or 16% carbamide peroxide and 35% or 40% hydrogen peroxide) or whether contact with pigments occurred immediately after gel removal. Thus, previous results suggesting increased susceptibility of dental structures to staining do not appear to apply to real clinical conditions. This highlights the importance of adopting a broader and contextualized perspective when assessing the need for dietary restrictions during bleaching. The findings of this study align with those of a systematic review that evaluated the influence of pigments derived from smoking on bleaching outcomes, which concluded that bleaching effectiveness is similar in smokers and non-smokers [27]. This may be explained by the fact that substances believed to cause extrinsic stains, such as cigarette smoke and dietary pigments, are composed of macromolecular chains and therefore are unlikely to penetrate human enamel. Only low molecular weight compounds can diffuse through enamel [20,26,27]. Together, these findings suggest that the dentin substrate on which the bleaching agent exerts its oxidative effect is probably similar regardless of the patient's smoking habits or dietary practices during bleaching [9,22,30].

De Geus, et al., showed that smokers had slightly darker teeth one month after bleaching, probably due to the deposition of cigarette smoke stains on the tooth surface [8,26]. Similar results were found by Chen, et al., the group of patients who continued daily rinses with coffee for three weeks after the end of bleaching exhibited a significant reduction in brightness (lower ΔL^*) [11]. However, the authors stated that although this difference was statistically significant, the change in brightness was small and may not have clinical relevance [11]. It is likely that the difference would become more evident after several years, with individuals who consume more pigments having darker teeth. Therefore, longer-term follow-up studies may help explain whether diet influences the longevity of bleaching results.

Bleaching treatment uses peroxide-based oxidizing agents that diffuse into the dental structure and produce reactive oxygen species to oxidize organic pigment molecules [31]. However, the low molecular weight of peroxides allows them to diffuse into the pulp tissue, leading to the most common adverse effect: transient post-bleaching tooth sensitivity [32-34]. In the studies examined, there was no increase in the risk or intensity of sensitivity in groups consuming pigmented beverages compared to control groups, except in the studies by Hass, et al., and Campos, et al., [9,22].

Although Hass, et al., observed that exposure to Coca-Cola did not affect bleaching efficacy, significantly higher scores were detected for sensitivity intensity in patients who consumed Coca-Cola compared to those who did not [9]. It should be noted, however, that Coca-Cola has a lower pH (2.53) than the other substances evaluated in the remaining studies [9]. Similarly, the pH of the grape juice used in the study by Campos, et al., may also explain the higher relative risk observed, as the study demonstrated a significant association between grape juice exposure and the occurrence of sensitivity during in-office bleaching [23]. The consumption of acidic beverages during meals has been associated with dental erosion and may therefore contribute to some degree of tooth sensitivity [23]. Thus, it seems clinically prudent to advise patients to reduce exposure to acidic beverages during bleaching treatment.

Another important point to highlight is the impossibility of randomization in some studies, since this procedure would require that all patients had the same chance of being allocated to any group. In some studies, participants needed to habitually consume Coca-Cola, wine or coffee; it would not be ethically appropriate to require patients who do not usually consume these beverages to begin doing so for study purposes. Nevertheless, these clinical findings are stronger than those obtained under laboratory conditions.

One limitation of the included studies is the difficulty of controlling dietary and hygiene habits, which may influence clinical outcomes. Furthermore, the post-treatment follow-up periods were relatively short. Therefore, well-designed clinical trials with longer follow-up periods that consider participants' diets are needed to provide more precise information on the influence of dietary restrictions on the efficacy, durability and side effects of dental bleaching.

Conclusion

The findings suggest that the ingestion of dietary pigments during bleaching is not a decisive factor for clinical outcomes. Tooth sensitivity also does not appear to be influenced by diet. However, the limited number of studies and methodological biases do not allow for definitive conclusion.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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Study Protocol

Prospective Register of Systematic Reviews - CRD42022359009

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None.

Data Availability Statement
Not applicable.

Ethical Statement
The project did not meet the definition of human subject research under the purview of the IRB according to federal regulations and therefore, was exempt.

Informed Consent Statement
Informed consent was taken for this study.

Authors' Contributions
Elma Vieira Takeuchi had the idea for the article; Elma Vieira Takeuchi and Beatriz Lopes de Oliveira performed the literature search; Elma Vieira Takeuchi, Beatriz Lopes de Oliveira, Jesuina Lamartine Nogueira Araújo, Aryvelto Miranda Silva, Cristiane de Melo Alencar performed the data analysis; Elma Vieira Takeuchi, Cristiane de Melo Alencar and Cecy Martins Silva drafted and/or critically revised the work.

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