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Vital Bleaching Influences the Bond Strength of Adhesive Systems to Enamel and Dentin: A Systematic Review and Meta-Analysis of *In Vitro* Studies

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Clinical Relevance

Vital bleaching impairs the bonding of adhesive systems to enamel and dentin. Thus, restoration placement should be delayed for at least two weeks after completion of bleaching procedures.

SUMMARY

Objective: This systematic review evaluates the influence of vital bleaching on the bond strength of adhesive systems to enamel and dentin.

Methods: This review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA). *In vitro* studies comparing the bond strength of bleached and unbleached enamel and dentin were searched at the electronic databases—PubMed/MEDLINE, Scopus, and Web of Science—with no limit on year or language. The studies were screened and had data extracted by two reviewers independently. Bond strength data were meta-analyzed using the inverse variance method and the random effect model ($p \leq 0.05$).

Results: The electronic search provided 4941 eligible studies, and 52 were included in the systematic review and the meta-analysis. The global meta-analysis showed that bleaching impairs the bond strength of adhesive systems to enamel and dentin ($p<0.001$; mean difference [MD]: -0.96;

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confidence interval [CI]: -1.18 to -0.73), regardless of the bleaching agent (p<0.001; MD: -9.98; CI: -1.37 to -0.58) or substrate (p<0.001; MD: -0.89; CI: -1.12 to -0.66). The detrimental effect of bleaching on bond strength was not observed after two and three weeks after bleaching (p=0.1; MD: -0.39; CI: -0.84 to 0.65; and p=0.18; MD: -0.99; CI: -2.45 to 0.47, respectively).

Conclusion: This systematic review and meta-analysis demonstrated that vital bleaching impairs the bonding of adhesive systems to enamel and dentin, and this adverse effect persists for two weeks.

INTRODUCTION

Vital dental bleaching is one of the most used conservative treatments to improve the appearance of teeth.[1,2] With the public desire for whiter teeth, tooth bleaching is considered a relatively safe and straightforward procedure.[3,4] In-office administered and at-home bleaching techniques use different concentrations of hydrogen peroxide or its precursor, carbamide peroxide, as the active ingredient, with similar overall outcomes in terms of comfort and bleaching efficacy.[5] The bleaching process includes a chemical oxidation of the chromogens inside the tooth structure by free radicals from the ionic dissociation of the hydrogen peroxide.[6,7] The high reactivity and nonspecific nature of free radicals are associated with certain undesirable side effects on dental tissues, as increased porosity, surface roughness, and decreased protein concentration.[8] The influence of vital bleaching agents on the physical and esthetic properties of restorative materials[9] and bond strength of restorative materials to enamel and dentin[7] was also reported.

The potential reduction of the adhesive bond strength after bleaching is a concern as esthetic restorative procedures are usually required after bleaching.[10] Indeed, several studies have shown a detrimental effect on the bonding of adhesive systems to previously bleached enamel and dentin.[7,11] The residual hydrogen peroxide and free radicals within the dental tissues had a negative influence on the infiltration of the adhesive into the substrate, on the polymerization of adhesive systems, resulting in lower bond strength values.[6,8,12] On the other hand, the detrimental effect of bleaching agents on enamel and dentin seems to be reversible.[7,10,13] Thus, a waiting time seems to be necessary for naturally releasing the residual oxygen from the dental structure and overcoming its effect.[14] However, some studies found that dental bleaching does not affect the adhesive systems bond strength to enamel[8,14,15] and dentin[4,16] so the waiting time after bleaching would not be necessary.[14] The bleaching agent, concentration and protocol (duration of application),[15,17,18] and the type of adhesive system (composition and etching strategy)[4,16] explain these different results, so the deleterious effect of bleaching seems to be material and time dependent. Furthermore, differences in laboratory protocols, mainly regarding the storage conditions (artificial saliva),[8] could partly explain the results, whereas *in vitro* studies generally present methodological variations.[19]

Nevertheless, laboratory studies on adhesive dentistry are still valuable to provide data for the evaluation of experimental variables as bond strength tests can predict, to some degree, the clinical performance of adhesive systems or dental substrate conditions.[20] Thus, given that the effect of bleaching on bonding is controversial considering the time elapsed after bleaching, this systematic review and meta-analysis aimed to evaluate the influence of vital bleaching and the time elapsed after bleaching on the bond strength of adhesive systems to enamel and dentin.

METHODS

Protocol

This study was conducted following the recommendations of the Cochrane Handbook[21] and written according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[22] Whereas this systematic review only included *in vitro* studies, it was not registered in any database.

Information Sources and Search Strategy

A literature search was conducted in the electronic databases PubMed/MEDLINE, Scopus, and Web of Science for articles published until September 2019. The search was conducted with no limits in publication year or language. The search strategy was defined based on the following focused question: Do vital bleaching and the time elapsed after bleaching influence the bond strength of adhesive systems to enamel and dentin?

A combination of specific medical subject headings (MeSH terms) and free text words were used to create a search strategy for the PubMed/MEDLINE database as follows:

(tensile strength[MeSH Terms]) OR tensile strength) OR shear strength[MeSH Terms]) OR shear strength) OR tensile) OR shear) OR micro tensile) OR microtensile) OR micro shear) OR micro shear) OR bond strength) OR bond*) OR *bond)) AND (tooth bleaching[MeSH Terms]) OR peroxides[MeSH Terms]) OR tooth bleaching agents[MeSH Terms])

OR hydrogen peroxide[MeSH Terms]) OR carbamide peroxide) OR bleaching) OR whitening) OR tooth bleaching) OR peroxides) OR tooth bleaching agents) OR hydrogen peroxide). A sensitive search strategy was adapted for Scopus and Web of Science databases. The search results were cross-checked to find and remove duplicates.

Selection, Inclusion, and Exclusion Criteria

Eligible articles were selected independently by two authors (TS and JO), reviewing titles and abstracts according to the following inclusion criteria: studies that evaluated the bond strength of adhesive systems to coronal bleached enamel and/or dentin and considered any time elapsed after bleaching. The full-text selected studies were screened in detail, by the same reviewers, for the final decision about inclusion. Full-text articles that could not be obtained were requested to the authors by e-mail. Studies without a control group (unbleached substrate) and that did not present bond strength data with mean and standard deviation in MPa were excluded. The interexaminer agreement was calculated (k=0.9). Any disagreement was solved via consensus-based discussions with a third reviewer (ROR).

Data Extraction

One reviewer collected the data of the included studies using a predefined data extraction sheet. For each paper, variables including publication details (authors and publication year, first author's country) and research methodology (origin and type of teeth: human or bovine, primary or permanent teeth, number of teeth per group, substrate, bonding test, bleaching agent, bleaching agent manufacturer, adhesive system, and the time elapsed after bleaching) were systematically extracted.

Risk of Bias of Individual Studies

Risk of bias was assessed based on a previous study[23] and adapted to consider the following items: randomization of teeth for experimental groups, blinding of the operator to bleached and unbleached substrate, sample size calculation, restorative materials used following manufacturers' instructions, restorative procedures by a single operator, blinding the operator of testing machine, and failure analysis.

If it was possible to find the information in the text, the study received a yes; if the parameter was not recognized in the paper, a no was applied to the table. The risk of bias was classified according to the sum of "yes" received as follows: 1 to 3 = high; 4 to 5 = medium; 6 to 7 = low risk of bias.

Data Analyses

Meta-analyses were performed using Review Manager software (RevMan version 5.3 software, Cochrane Collaboration, Copenhagen, Denmark). The standardized mean difference was calculated for the bond strength means from each primary included study, considering the experimental (bleached groups) and control (no bleaching treatment before bonding procedures) groups, using the inverse variance method and the random effect model; $p \leq 0.05$ (Z-test) was considered significant.

For studies that evaluated more than one time elapsed after bleaching and more than one bleaching agent, adhesive, or substrate, means were combined into one mean and standard deviation of bond strength for each group (experimental and control) using a formula suggested by Cochrane Statistical guidelines. To illustrate the meta-analysis, forest charts were created. Statistical heterogeneity of the treatment effect among studies was assessed using the Cochran Q test and inconsistency I^2, with a p-value of 0.5. The value of >25%, 50%, and 75% represent low, moderate, and high heterogeneity, respectively.[24]

RESULTS

Study Selection

Figure 1 presents the flow diagram of the study selection process. The search strategy identified a total of 4941 potentially relevant studies (duplicates excluded). Ultimately, 52 studies met the eligibility criteria and were included in this review, with 42 evaluating the effect of bleaching on the bonding to enamel and 7 to dentin; 3 studies included both substrates.

Characteristics of the Included Studies

A detailed summary of the included studies is presented in Table 1. The included studies were published between 1992 and 2019, almost all in English (one study was in Chinese), and most were conducted by Brazilian (20 studies), Iranian (eight studies), and Indian (six studies) researchers. The time elapsed after bleaching ranged from immediately (52 studies) to one month (one study); in 36 studies, the bonding procedures were postponed for one week after bleaching, in 23 studies for two weeks, and in four studies, for four weeks after the bleaching procedure. The majority of the studies conducted a shear bond strength test (34 studies), followed by the microtensile bond strength test (nine studies). Enamel was the most evaluated substrate (42 studies); seven studies considered only dentin as a bonding substrate, and only three studies

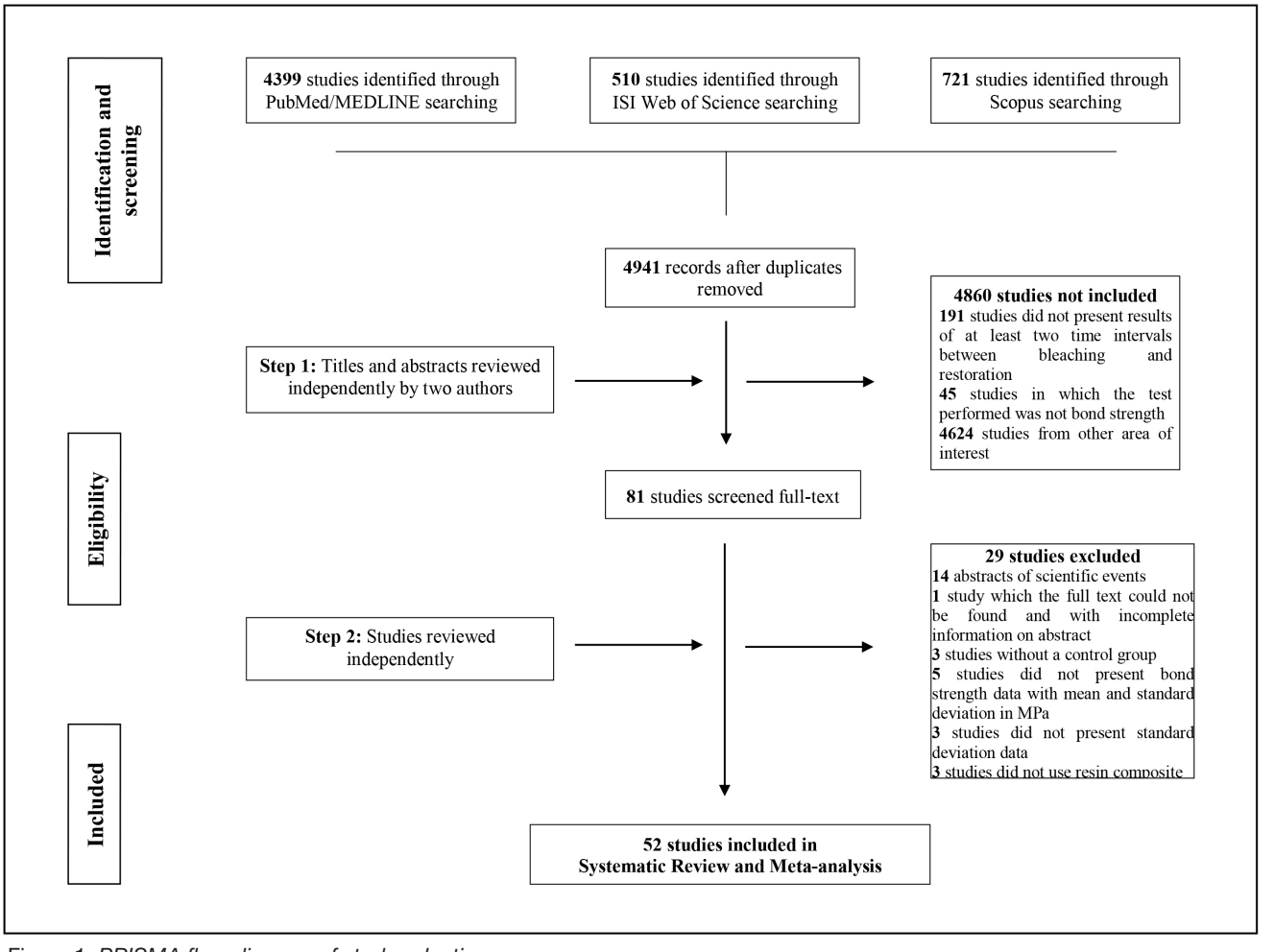


Figure 1. *PRISMA flow diagram of study selection.*

included both substrates. Human teeth were used in 36 studies, while 16 studies used bovine teeth. Bleaching agents considered in the included studies—hydrogen peroxide and carbamide peroxide—showed a wide variety of concentrations (range from 4% to 40%). The adhesive systems and composite resins evaluated were also very distinct.

Meta-analysis

Figure 2 presents the forest plot of the analysis between bleached and unbleached substrates. The meta-analysis favored unbleached substrates (control groups), with an effect size of -0.96, 95% confidence interval (CI) between -1.18 and -0.73, with a heterogeneity of 83%. The negative effect of bleaching on bond strength was also verified for both bleaching agents: carbamide peroxide, with an effect size of -0.98 (95% CI: -1.37 to -0.58) and hydrogen peroxide, with an effect size of -0.93 (95% CI: -1.14 to -0.73) (Figure 3); and both substrates: enamel, with an effect size of -0.90 (95% CI: -1.20 to -0.70) and dentin, with an effect size of -0.83 (95% CI: -1.37 to -0.30) (Figure 4).

The meta-analysis data for the time elapsed after bleaching are presented in Figure 5). Data were analyzed according to four subgroups (immediate until 24 hours postbleaching, one week, two weeks, and three weeks). Lower bond strength was observed for bleached groups at immediate (Figure 5), with an effect size of -2.03 (95% CI: -2.4 to -1.67) and one-week subgroups (Figure 5), with an effect size of -0.64 (95% CI: -0.97 to -0.32). The detrimental effect of bleaching on bond strength was not observed after two and three weeks after bleaching (with an effect size of -0.39, 95% CI: -0.84 to -0.07; and -0.99, 95% CI: -2.45 to 0.47, respectively; Figure 5).

Assessment of Risk of Bias and Quality of Evidence of the Included Studies

Table 2 presents the final assessment of the risk of bias in the included studies. Most of the studies were

Table 1: Characteristics of the Included Studies

Study	Country	Origin and Type of Teeth	Primary Outcome	Bleaching Agent[a]	Adhesive System[b]	Time Elapsed After Bleaching
Titley & others[33]	Canada	Bovine incisors	Enamel SBS	10% CP	Scotchbond 2 (3M Oral Care)	1 day 1 week
Titley & others[40]	United States	Human premolars	Enamel SBS	35% HP	Scotchbond Dual Cure Dental Adhesive (3M Oral Care)	1 day
Dishman & others[13]	United States	Human third molars	Enamel SBS	25% HP	Universal Bond 2 (L.D. Caulk)	1 day 1 week 1 month
Vyver & others[41]	South Africa	Human anterior teeth	Enamel SBS	35% HP	Scotchbond Multi-Purpose (3M Oral Care)	1 week 2 weeks
Demarco & others[26]	Brazil	Human third molars	Dentin TBS	30% HP	Optibond (Kerr)	1 week
Spyrides & others[18]	Brazil	Bovine incisors	Dentin SBS	35% HP 35% CP 10% CP	Single Bond (3M Oral Care)	1 week
Cavalli & others[36]	Brazil	Human third molars	Enamel SBS	10% CP 20% CP 10% CP 16% CP	Scotchbond Multipurpose Adhesive (3M Oral Care)	1 day 1 week 2 weeks 3 weeks
Sun & others[25.b]	China	Human molars	Enamel SBS	—	—	1 week 2 weeks
Kaya & Türkün[28]	Turkey	Human premolars	Dentin SBS	35% HP	Clearfil SE Bond (Kuraray Noritake)	1 day 1 week
Türkün & Kaya[34]	Turkey	Bovine incisors	Enamel SBS	10% CP 16% CP 22% CP	Clearfil SE Bond (Kuraray Noritake)	1 week
Miyazaki & others[42]	Japan	Bovine incisors	Enamel SBS	35% HP	Fluoro Bond (Shofu) Mac Bond II (Tokuyama) Clearfil SE Bond (Kuraray Noritake) Single Bond (3M Oral Care)	1 day
Unlu & others[2]	Turkey	Human incisors	Enamel SBS	35% HP 10% CP	Clearfil SE Bond (Kuraray Noritake)	1 day 1 week 2 weeks

Abbreviations: CP. carbamide peroxide; HP. hydrogen peroxide.
[a]According to description in the study.
[b]Information not obtained from the study translation.

Borges & others[35]	Brazil	Human premolars	Enamel SBS	35% HP 35% CP 6.5% HP	Scotchbond Multi-Purpose Plus (3M Oral Care)	1 day 1 week 2 weeks 3 weeks
Wilson & others[43]	United States	Human teeth	Enamel UTS	6.5% HP 10% CP	Single Bond Plus (3M Oral Care)	1 day 1 week 2 weeks
Barbosa & others[3]	Brazil	Human third molars	Enamel and Dentin UTS	35% HP	Single Bond (3M Oral Care)	1 week 2 weeks
Barbosa & others[30]	Brazil	Human teeth	Enamel and Dentin SBS	16% CP	Single Bond (3M Oral Care)	1 week 2 weeks
Hussain & Wang[44]	China	Human molars	Enamel SBS	10% CP 38% HP	Adper Single Bond 2 (3M Oral Care)	1 hour 1 day
Bittencourt & others[31]	Brazil	Human third molars	Enamel and Dentin SBS	35% HP	Adper Single Bond Plus (3M Oral Care)	1 week 2 weeks 3 weeks
Khoroushi & Aghelinejad[45]	Iran	Human incisors	Enamel SBS	20% CP	OptiBond FL OptiBond Solo Plus OptiBond All-in-One (Kerr)	1 week
da Silva & others[46]	Brazil	Human third molars	Enamel μTBS	38% HP	Adper Single Bond Plus (3M Oral Care)	1 week
Danesh-Sani & Esmaili[12]	Iran	Human third molars	Enamel SBS	9.5% HP	Not informed	1 week
Lago & others[6]	Brazil	Bovine teeth	Enamel μTBS	35% HP	Adper Single Bond 2 (3M Oral Care)	1 day
Lima & others[32]	Brazil	Bovine incisors	Enamel μSBS	16% CP 35% HP	Adper Single Bond 2 (3M Oral Care)	1 day 2 weeks
Mazaheri & others[10]	Iran	Human molars	Enamel SBS	9.5% HP	Single Bond (3M Oral Care)	1 week
Tabatabaei & others[29]	Iran	Bovine incisors	Dentin SBS	35% CP	Clearfil SE Bond (Kuraray Noritake)	1 week
Vidhya & others[47]	India	Human incisors	Enamel SBS	38% HP	Adper Single Bond (3M Oral Care)	2 weeks
Braz & others[4]	Brazil	Bovine incisors	Dentin SBS	10% CP	Adper Single Bond 2 (3M Oral Care) Prime & Bond 2.1 (Dentsply Sirona) AdheSE (Ivoclar Vivadent) Clearfil SE Bond (Kuraray Noritake)	1 day 1 week
Khoroushi & Saneie[16]	Iran	Human molars	Dentin SBS	20% CP	Optibond FL Optibond Solo Plus Optibond All-in-One (Kerr)	1 week

Tostes & others[48]	Brazil	Bovine incisors	Enamel μSBS	35% HP	One-Step (Bisco)	1 week
Bittencourt & others[17]	Brazil	Human third molars	Enamel μSBS	35% HP 38% HP	Ambar (FGM)	1 week 2 weeks
Khoroushi & Ghazalgoo[49]	Iran	Human molars	Enamel SBS	9.5% HP	Single Bond (3M Oral Care)	1 day 1 week 2 weeks
Khamverdi & others[50]	Iran	Human incisors	Enamel SBS	40% HP	Adper Single Bond Plus (3M Oral Care)	1 day 1 week
Vohra & Kasah[51]	United Kingdom	Human third molars	Enamel μTBS	10% CP	Prime & Bond NT (Dentsply Sirona)	3 hours
Miranda & others[52]	Brazil	Human premolars and molars	Enamel μTBS	37.5% HP	Adper Single Bond 2 (3M Oral Care)	1 week 2 weeks
Arumugam & others[38]	India	Human incisors	Enamel SBS	35% CP	Not informed	2 weeks
Anil & others[53]	India	Human anterior teeth	Enamel SBS	37.5% HP	Single Bond Adper SE Plus (3M Oral Care)	4 days
Cura & others[15]	Spain	Bovine incisors	Enamel μTBS	10% CP 10% HP	Adper Scotchbond 1 XT (3M Oral Care)	1 day 3 days 1 week 2 weeks
de Castro & others[54]	Brazil	Bovine incisors	Enamel μSBS	35% HP	Scotchbond (3M Oral Care)	1 day 2 weeks
Kadiyala & others[55]	India	Human incisors	Enamel SBS	35% CP	Adper Single Bond 2 (3M Oral Care)	1 week
Subramonian & others[37]	India	Human premolars	Enamel SBS	37.5% HP	Adper Single Bond (3M Oral Care)	3 weeks
Pimentel & others[14]	Brazil	Bovine incisors	Enamel SBS	35% HP	Single Bond 2 (3M Oral Care)	1 day 3 days 1 week 2 weeks 4 weeks
Kavitha & others[56]	India	Human incisors	Enamel SBS	35% CP	Magic Bond (Vigodent)	1 week
Alencar & others[11]	Brazil	Bovine incisors	Enamel μTBS	35% HP	Natural Bond DE (Nova DFL)	1 week
Türkmen & others[57]	Turkey	Human incisors	Enamel SBS	35% HP 38% HP	Clearfil Tri S Bond (Kuraray Noritake) Adper Single Bond (3M Oral Care)	1 week
Svizero & others[58]	Brazil	Bovine incisors	Enamel SBS	35% HP	Adper Single Bond 2 (3M Oral Care)	2 weeks
Oliveira & others[8]	Brazil	Bovine incisors	Enamel μTBS	20% CP	Single Bond II (3M Oral Care)	2 weeks

Ismail & others[27]	United States	Human third molars	Dentin μTBS	35% HP	OptiBond FL (Kerr)	1 week
Topcu & others[7]	Turkey	Human third molars	Enamel μTBS	10% CP 16% CP 35% HP	Single Bond Universal (3M Oral Care)	1 week 2 weeks
Santos & others[59]	Brazil	Bovine incisors	Enamel μSBS	4% HP	Adper Single Bond 2 (3M Oral Care)	1 day 1 week
Nari-Ratih & Widyastuti[1]	Indonesia	Human premolars	Enamel SBS	40% HP	XP Bond (Dentsply Sirona)	2 weeks
Nair & others[39]	India	Human anterior teeth	Enamel SBS	35% CP	Scotchbond (3M Oral Care)	2 weeks
Halabi & others[60]	Japan	Bovine incisors	Enamel μSBS	35% HP	Clearfil SE Bond 2 (Kuraray Noritake) G-Premio Bond (GC)	1 week

classified as having a high risk of bias due to the sample size calculation, random sequence generation, a single operator to perform the restorative procedures, and blinding the operator of the testing machine (outcome assessment). Only three studies described the sample size calculation, and 21 articles did not inform the failure analysis after the bonding test. Only two studies had a medium risk of bias. It was not possible to assess the risk of bias of one Chinese study.

DISCUSSION

Our systematic review and meta-analysis was the first to provide the narrative synthesis and quantitative analysis of the pooled data from laboratory studies evaluating the influence of bleaching and the time elapsed after bleaching on the bond strength of adhesive systems to enamel and dentin. The study included 52 individual studies with no limitation in time and language, and all of them were included in the meta-analysis. The pooled bond strength data showed a statistically significant difference in the bond strength of adhesive systems to bleached enamel and dentin compared with unbleached substrates.

Vital tooth bleaching, using hydrogen peroxide or carbamide peroxide, has the potential to induce microstructural changes in dental substrates,[1,7,33] mainly when peroxides are used in high concentrations.[34] These possible effects on enamel and dentin may imply a reduction of adhesive systems bond strength to bleached substrates. Attin and others[9] conducted a systematic review, and similar to the results of our study, they reported a reduced bonding of adhesive restorations to bleached enamel and dentin. They suggested delaying adhesive restorations for at least one to three weeks after bleaching. Nevertheless, the present study determined that there were significant differences in bonding to bleached vs unbleached substrates even after one week elapsed after bleaching—that is, seven days after bleaching is not sufficient to counteract the effect of blenching on bonding.

Stratifying our meta-analysis by the time elapsed after bleaching, different results were uncovered. Most studies evaluated the effect of bleaching on bonding when restorations were performed after 24 hours and one week after bleaching. It was found that few studies have compared the bond strength to bleached and unbleached substrates after more extended periods after bleaching (more than two weeks).[31,35,36,37] Even so, the detrimental effect of bleaching disappeared when the time elapsed after bleaching was at least two weeks. This is the main result of this study, providing relevant advice for clinical practice.

Our results demonstrate that tooth bleaching produces adverse effects on both enamel and dentin bond strength. However, among the included studies, most of them evaluated enamel as a bonding substrate, and only 10 studies evaluated the effect of bleaching on bonding to dentin. Thus, studies evaluating the effects of bleaching on dentin adhesion are needed to understand the effects of bleaching on this substrate and to confirm our findings. Our study also determined that both hydrogen peroxide and carbamide peroxide impair the bond strength, even though a larger number of studies had evaluated hydrogen peroxide, and only eight primary studies compared the two agents directly. In the present study, however, the meta-analysis was not stratified by bleaching agent concentration, because of a wide range of concentration of each bleaching agent found in included studies, which would require

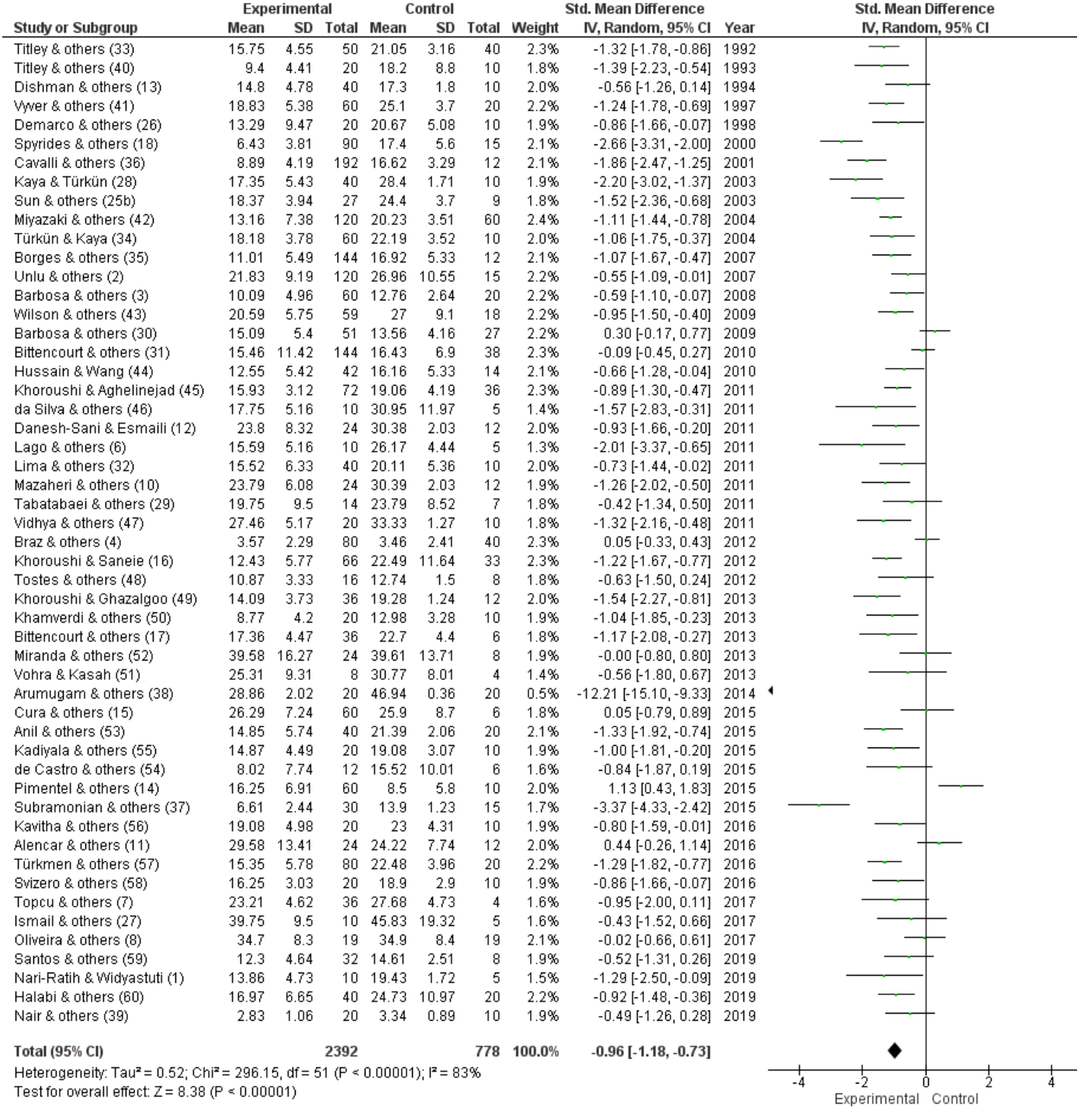


Figure 2. *Forest plot of the included studies.*

extensive meta-analysis. Furthermore, bleaching agents in different concentrations were associated with similar bond strength values, as found in several included primary studies.[7,18,34,36]

High heterogeneity was found in the overall and subgroups meta-analysis, as usually seen in the previous meta-analysis of laboratory studies.[4,27,38,39] High heterogeneity across the included studies may be related to the different methods used to evaluate the bond strength (different mechanical tests), type of tooth undergoing bleaching and restoration, adhesive systems, and bonding strategies. A high risk of bias

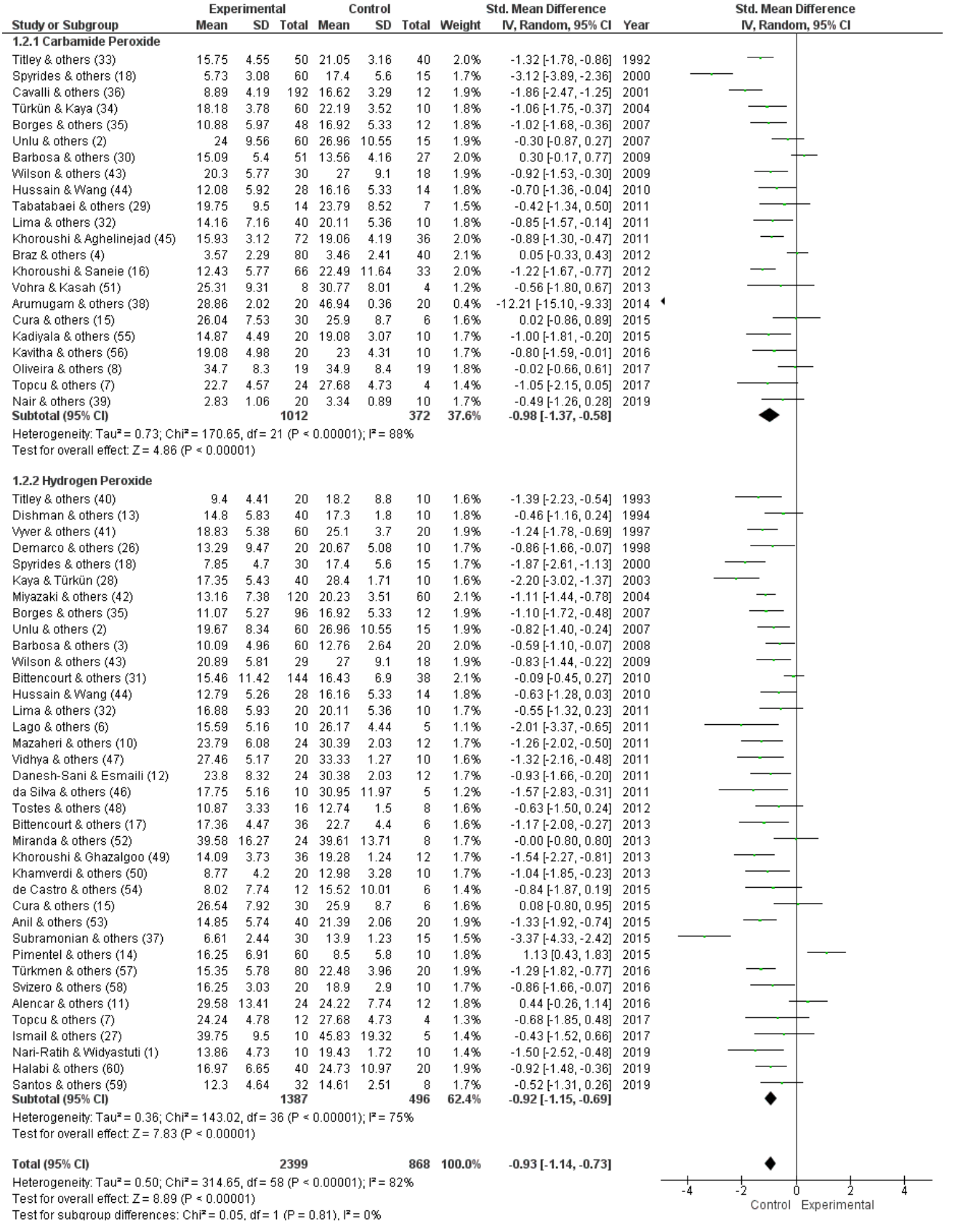


Figure 3. *Meta-analysis findings considering bleaching agents as a subgroup.*

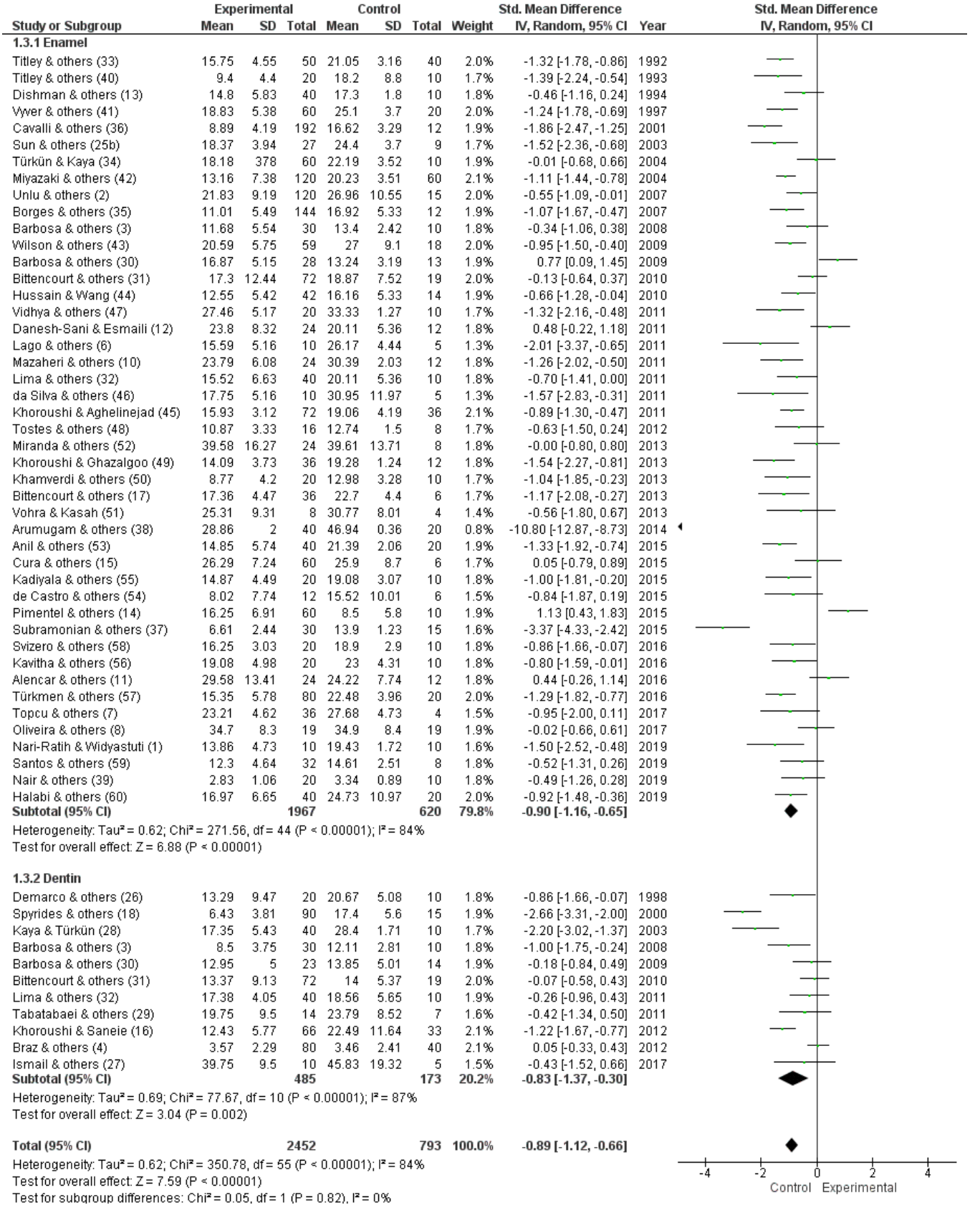


Figure 4. *Meta-analysis findings considering the substrate, enamel and dentin, as a subgroup.*

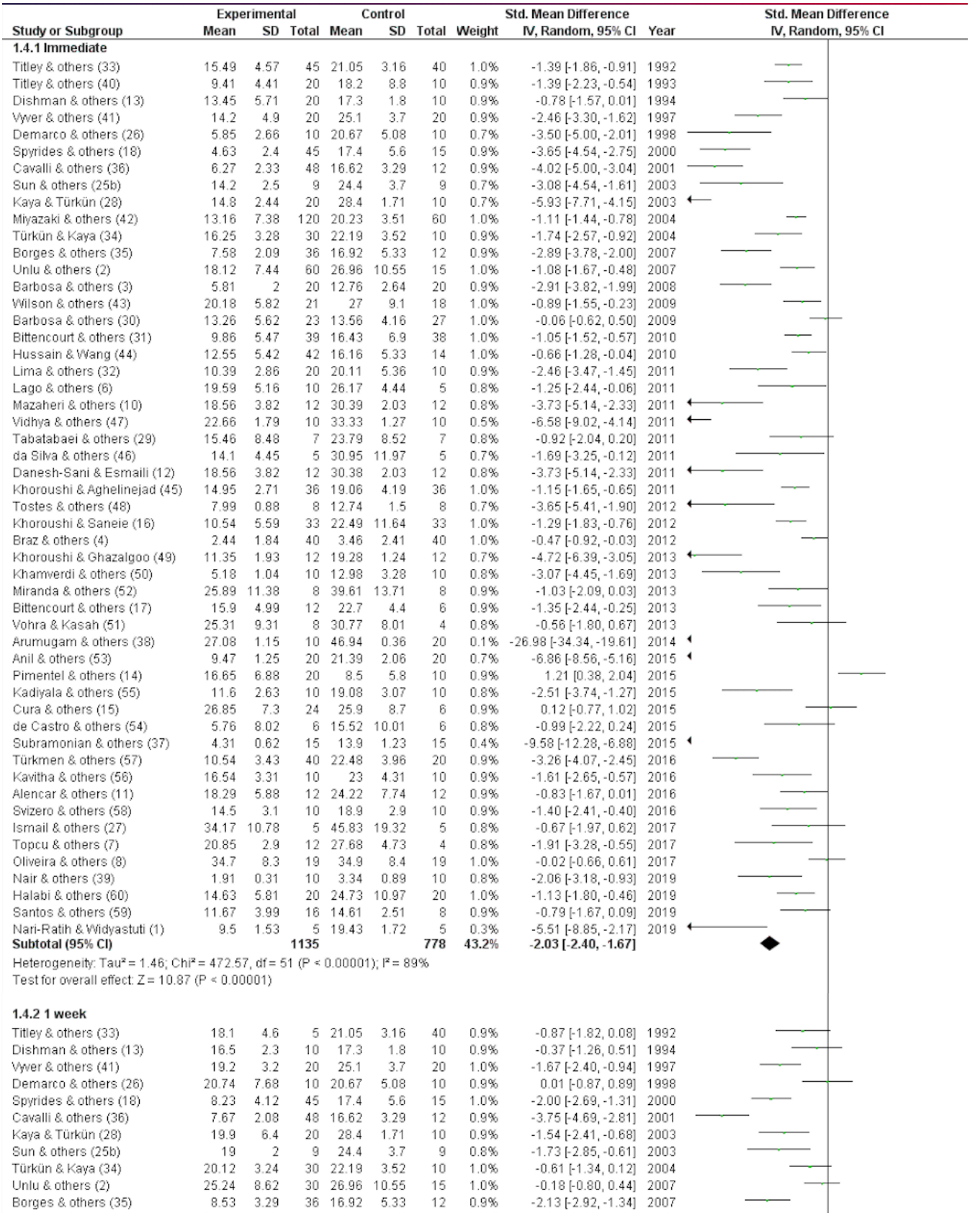
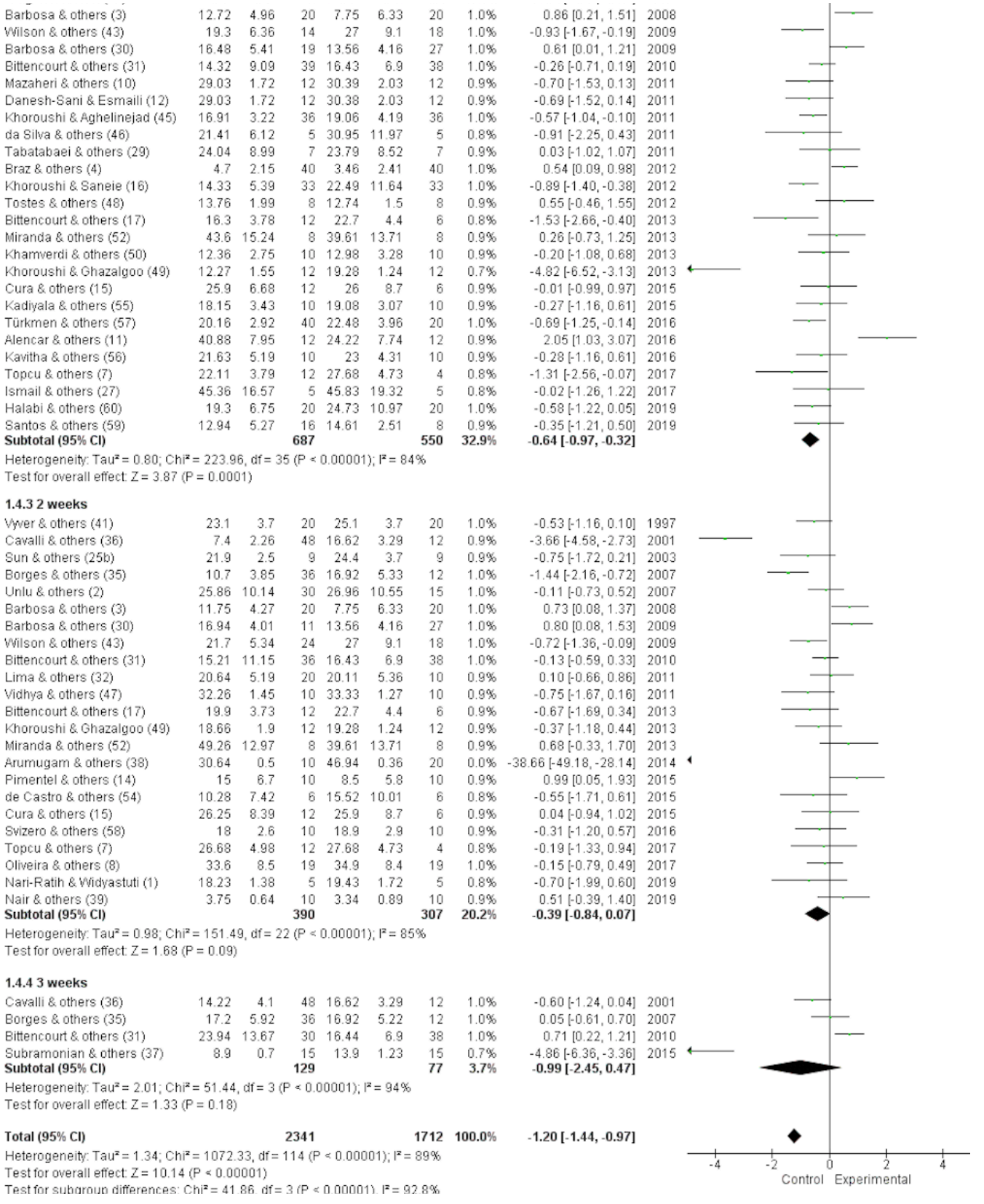


Figure 5. Meta-analysis findings for the time elapsed after bleaching.



Barbosa & others (3)	12.72	4.96	20	7.75	6.33	20	1.0%	0.86 [0.21, 1.51]	2008
Wilson & others (43)	19.3	6.36	14	27	9.1	18	1.0%	-0.93 [-1.67, -0.19]	2009
Barbosa & others (30)	16.48	5.41	19	13.56	4.16	27	1.0%	0.61 [0.01, 1.21]	2009
Bittencourt & others (31)	14.32	9.09	39	16.43	6.9	38	1.0%	-0.26 [-0.71, 0.19]	2010
Mazaheri & others (10)	29.03	1.72	12	30.39	2.03	12	0.9%	-0.70 [-1.53, 0.13]	2011
Danesh-Sani & Esmaili (12)	29.03	1.72	12	30.38	2.03	12	0.9%	-0.69 [-1.52, 0.14]	2011
Khoroushi & Aghelinejad (45)	16.91	3.22	36	19.06	4.19	36	1.0%	-0.57 [-1.04, -0.10]	2011
da Silva & others (46)	21.41	6.12	5	30.95	11.97	5	0.8%	-0.91 [-2.25, 0.43]	2011
Tabatabaei & others (29)	24.04	8.99	7	23.79	8.52	7	0.9%	0.03 [-1.02, 1.07]	2011
Braz & others (4)	4.7	2.15	40	3.46	2.41	40	1.0%	0.54 [0.09, 0.98]	2012
Khoroushi & Saneie (16)	14.33	5.39	33	22.49	11.64	33	1.0%	-0.89 [-1.40, -0.38]	2012
Tostes & others (48)	13.76	1.99	8	12.74	1.5	8	0.9%	0.55 [-0.46, 1.55]	2012
Bittencourt & others (17)	16.3	3.78	12	22.7	4.4	6	0.8%	-1.53 [-2.66, -0.40]	2013
Miranda & others (52)	43.6	15.24	8	39.61	13.71	8	0.9%	0.26 [-0.73, 1.25]	2013
Khamverdi & others (50)	12.36	2.75	10	12.98	3.28	10	0.9%	-0.20 [-1.08, 0.68]	2013
Khoroushi & Ghazalgoo (49)	12.27	1.55	12	19.28	1.24	12	0.7%	-4.82 [-6.52, -3.13]	2013
Cura & others (15)	25.9	6.68	12	26	8.7	6	0.9%	-0.01 [-0.99, 0.97]	2015
Kadiyala & others (55)	18.15	3.43	10	19.08	3.07	10	0.9%	-0.27 [-1.16, 0.61]	2015
Türkmen & others (57)	20.16	2.92	40	22.48	3.96	20	1.0%	-0.69 [-1.25, -0.14]	2016
Alencar & others (11)	40.88	7.95	12	24.22	7.74	12	0.9%	2.05 [1.03, 3.07]	2016
Kavitha & others (56)	21.63	5.19	10	23	4.31	10	0.9%	-0.28 [-1.16, 0.61]	2016
Topcu & others (7)	22.11	3.79	12	27.68	4.73	4	0.8%	-1.31 [-2.56, -0.07]	2017
Ismail & others (27)	45.36	16.57	5	45.83	19.32	5	0.8%	-0.02 [-1.26, 1.22]	2017
Halabi & others (60)	19.3	6.75	20	24.73	10.97	20	1.0%	-0.58 [-1.22, 0.05]	2019
Santos & others (59)	12.94	5.27	16	14.61	2.51	8	0.9%	-0.35 [-1.21, 0.50]	2019
Subtotal (95% CI)			**687**			**550**	**32.9%**	**-0.64 [-0.97, -0.32]**	
Heterogeneity: Tau² = 0.80; Chi² = 223.96, df = 35 (P < 0.00001); I² = 84%									
Test for overall effect: Z = 3.87 (P = 0.0001)									
1.4.3 2 weeks									
Vyver & others (41)	23.1	3.7	20	25.1	3.7	20	1.0%	-0.53 [-1.16, 0.10]	1997
Cavalli & others (36)	7.4	2.26	48	16.62	3.29	12	0.9%	-3.66 [-4.58, -2.73]	2001
Sun & others (25b)	21.9	2.5	9	24.4	3.7	9	0.9%	-0.75 [-1.72, 0.21]	2003
Borges & others (35)	10.7	3.85	36	16.92	5.33	12	1.0%	-1.44 [-2.16, -0.72]	2007
Unlu & others (2)	25.86	10.14	30	26.96	10.55	15	1.0%	-0.11 [-0.73, 0.52]	2007
Barbosa & others (3)	11.75	4.27	20	7.75	6.33	20	1.0%	0.73 [0.08, 1.37]	2008
Barbosa & others (30)	16.94	4.01	11	13.56	4.16	27	1.0%	0.80 [0.08, 1.53]	2009
Wilson & others (43)	21.7	5.34	24	27	9.1	18	1.0%	-0.72 [-1.36, -0.09]	2009
Bittencourt & others (31)	15.21	11.15	36	16.43	6.9	38	1.0%	-0.13 [-0.59, 0.33]	2010
Lima & others (32)	20.64	5.19	20	20.11	5.36	10	0.9%	0.10 [-0.66, 0.86]	2011
Vidhya & others (47)	32.26	1.45	10	33.33	1.27	10	0.9%	-0.75 [-1.67, 0.16]	2011
Bittencourt & others (17)	19.9	3.73	12	22.7	4.4	6	0.9%	-0.67 [-1.69, 0.34]	2013
Khoroushi & Ghazalgoo (49)	18.66	1.9	12	19.28	1.24	12	0.9%	-0.37 [-1.18, 0.44]	2013
Miranda & others (52)	49.26	12.97	8	39.61	13.71	8	0.9%	0.68 [-0.33, 1.70]	2013
Arumugam & others (38)	30.64	0.5	10	46.94	0.36	20	0.0%	-38.66 [-49.18, -28.14]	2014
Pimentel & others (14)	15	6.7	10	8.5	5.8	10	0.9%	0.99 [0.05, 1.93]	2015
de Castro & others (54)	10.28	7.42	6	15.52	10.01	6	0.8%	-0.55 [-1.71, 0.61]	2015
Cura & others (15)	26.25	8.39	12	25.9	8.7	6	0.9%	0.04 [-0.94, 1.02]	2015
Svizero & others (58)	18	2.6	10	18.9	2.9	10	0.9%	-0.31 [-1.20, 0.57]	2016
Topcu & others (7)	26.68	4.98	12	27.68	4.73	4	0.8%	-0.19 [-1.33, 0.94]	2017
Oliveira & others (8)	33.6	8.5	19	34.9	8.4	19	1.0%	-0.15 [-0.79, 0.49]	2017
Nari-Ratih & Widyastuti (1)	18.23	1.38	5	19.43	1.72	5	0.8%	-0.70 [-1.99, 0.60]	2019
Nair & others (39)	3.75	0.64	10	3.34	0.89	10	0.9%	0.51 [-0.39, 1.40]	2019
Subtotal (95% CI)			**390**			**307**	**20.2%**	**-0.39 [-0.84, 0.07]**	
Heterogeneity: Tau² = 0.98; Chi² = 151.49, df = 22 (P < 0.00001); I² = 85%									
Test for overall effect: Z = 1.68 (P = 0.09)									
1.4.4 3 weeks									
Cavalli & others (36)	14.22	4.1	48	16.62	3.29	12	1.0%	-0.60 [-1.24, 0.04]	2001
Borges & others (35)	17.2	5.92	36	16.92	5.22	12	1.0%	0.05 [-0.61, 0.70]	2007
Bittencourt & others (31)	23.94	13.67	30	16.44	6.9	38	1.0%	0.71 [0.22, 1.21]	2010
Subramonian & others (37)	8.9	0.7	15	13.9	1.23	15	0.7%	-4.86 [-6.36, -3.36]	2015
Subtotal (95% CI)			**129**			**77**	**3.7%**	**-0.99 [-2.45, 0.47]**	
Heterogeneity: Tau² = 2.01; Chi² = 51.44, df = 3 (P < 0.00001); I² = 94%									
Test for overall effect: Z = 1.33 (P = 0.18)									
Total (95% CI)			**2341**			**1712**	**100.0%**	**-1.20 [-1.44, -0.97]**	
Heterogeneity: Tau² = 1.34; Chi² = 1072.33, df = 114 (P < 0.00001); I² = 89%									
Test for overall effect: Z = 10.14 (P < 0.00001)									
Test for subgroup differences: Chi² = 41.86, df = 3 (P < 0.00001), I² = 92.8%									

Table 2: *Quality Assessment of Included Studies (Risk of Bias)*

Study	Random Sequence Generation	Blinding	Sample Size Calculation	Materials According Manufacturers	Single Operator	Blinding the Operator of Testing Machine	Failure Analysis	Overall Rating
Titley & others[33]	N	N	N	Y	N	N	N	High
Titley & others[40]	Y	N	N	Y	N	N	N	High
Dishman & others[13]	N	N	N	N	N	N	N	High
Vyver & others[41]	Y	N	N	N	N	N	N	High
Demarco & others[26]	Y	N	N	N	N	N	N	High
Spyrides & others[18]	Y	N	N	N	N	N	N	High
Cavalli & others[36]	Y	N	N	N	N	N	N	High
Sun & others[25]	Y	N	N	Y	N	N	N	High
Kaya & Türkün[28]	Y	N	N	Y	N	N	Y	High
Türkün & Kaya[34]	N	N	N	Y	N	N	Y	High
Miyazaki & others[42]	Y	N	N	Y	N	N	Y	High
Unlu & others[2]	Y	N	N	N	N	N	Y	High
Borges & others[35]	Y	N	N	N	N	N	N	High
Wilson & others[43]	Y	N	N	Y	N	N	Y	High
Barbosa & others[3]	Y	N	N	N	N	N	Y	High
Barbosa & others[30]	Y	N	N	N	N	N	Y	High
Hussain & Wang[44]	Y	N	N	Y	N	N	Y	High
Bittencourt & others[31]	Y	N	N	Y	N	N	Y	High
Khoroushi & Aghelinejad[45]	Y	N	N	Y	N	N	N	High
da Silva & others[46]	Y	N	N	Y	N	N	Y	High
Danesh-Sani & Esmaili[12]	Y	N	Y	Y	N	N	N	High

Lago & others[6]	Y	N	N	Y	N	N	Y	High
Lima & others[32]	Y	N	N	Y	N	N	N	High
Mazaheri & others[10]	Y	N	N	Y	N	N	N	High
Tabatabaei & others[29]	Y	N	N	N	N	N	N	High
Vidhya & others[47]	Y	N	N	Y	N	N	Y	High
Braz & others[4]	N	N	N	N	N	N	N	High
Khoroushi & Saneie[16]	Y	N	N	Y	N	N	Y	High
Tostes & others[48]	Y	N	N	N	N	N	Y	High
Bittencourt & others[17]	Y	N	N	N	N	N	Y	High
Khoroushi & Ghazalgoo[49]	Y	N	N	N	N	N	Y	High
Khamverdi & others[50]	N	N	Y	N	N	N	Y	High
Vohra & Kasah[51]	Y	N	N	N	N	N	N	High
Miranda & others[52]	Y	N	N	N	N	N	Y	High
Arumugam & others[38]	N	N	N	N	N	N	N	High
Anil & others[53]	Y	N	N	Y	N	N	Y	High
Cura & others[15]	Y	N	N	N	N	N	N	High
de Castro & others[54]	Y	N	N	N	N	N	Y	High
Kadiyala & others[55]	Y	N	N	N	N	N	Y	High
Subramonian & others[37]	Y	N	N	N	N	N	N	High
Pimentel & others[14]	Y	N	N	Y	N	N	Y	High
Kavitha & others[56]	N	N	N	Y	N	N	Y	High
Alencar & others[11]	Y	N	N	N	N	N	N	High
Türkmen & others[57]	Y	N	N	Y	N	N	Y	High
Svizero & others[58]	Y	N	N	Y	Y	N	Y	Medium

Oliveira & others[8]	N	N	N	Y	N	N	Y	High
Ismail & others[27]	Y	N	Y	Y	Y	N	Y	Medium
Topcu & others[7]	Y	N	N	N	N	N	Y	High
Santos & others[59]	Y	N	N	N	N	N	Y	High
Nari-Ratih & Widyastuti[1]	N	N	N	N	N	N	N	High
Nair & others[1]	N	N	N	N	N	N	Y	High
Halabi & others[60]	N	N	N	N	N	N	Y	High

was also found, and the most common missing or unclear items were lack of sample size calculation, randomization, and blinding the operator on the outcome assessment. The high heterogeneity across the included studies and the high risk of bias are limitations of this systematic review, and for these, a random effects model was applied. Nevertheless, the number of included studies in the meta-analysis enabled reliable results and recommendations for clinicians regarding the time elapsed after bleaching to achieve a suitable bonding, though based on laboratory studies. Future clinical trials are needed to confirm the effect of bleaching on bonding to enamel and dentin as the time elapsed after bleaching.

Based on the current study findings, vital bleaching impairs the bonding of adhesive systems to enamel and dentin, and this adverse effect persists for two weeks.

CONCLUSION

Vital bleaching impairs the bonding of adhesive systems to enamel and dentin, and this adverse effect persists for two weeks.

Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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