Restor Dent Endod. 2023 Aug;48(3):e26
https://doi.org/10.5395/rde.2023.48.e26
eISSN 2234-7666

Restorative Dentistry & Endodontics RDE

Research Article

Impact of combined at-home bleaching and whitening toothpaste use on the surface and color of a composite resin

Carolina Meneghin Barbosa [1*], **Renata Siqueira Scatolin** [1], **Waldemir Francisco Vieira-Junior** [2], **Marcia Hiromi Tanaka** [1], **Laura Nobre Ferraz** [1]

[1]Hermínio Ometto Foundation, University of Araras, Araras, SP, Brazil
[2]São Leopoldo Mandic Institute and Dental Research Center, Campinas, SP, Brazil

Received: Feb 1, 2023
Revised: Mar 27, 2023
Accepted: Apr 27, 2023
Published online: Jul 26, 2023

Citation
Barbosa CM, Scatolin RS, Vieira-Junior WF, Tanaka MH, Ferraz LN. Impact of combined at-home bleaching and whitening toothpaste use on the surface and color of a composite resin. Restor Dent Endod 2023;48(3):e26.

***Correspondence to**
Carolina Meneghin Barbosa, DDS
Hermínio Ometto Fundation, University of Araras, Av. Dr. Maximiliano Baruto, 500, Araras, SP 13607-339, Brazil.
Email: carolinameneghinbarbosa@gmail.com

Funding
This study was financed by the Foundation for Research Support of the State of São Paulo (FAPESP), under the process number 2020/13572-6.

Conflict of Interest
No potential conflict of interest relevant to this article was reported.

ABSTRACT

Objective: This *in vitro* study aimed to evaluate the effects of different whitening toothpastes on a composite resin during at-home bleaching with 10% carbamide peroxide.
Materials and Methods: Sixty samples (7 mm × 2 mm) were used for color and roughness analyses, while another 60 samples (3 mm × 2 mm) were utilized to assess microhardness. The factors analyzed included toothpaste, for which 5 options with varying active agents were tested (distilled water; conventional toothpaste; whitening toothpaste with abrasive agents; whitening toothpaste with abrasive and chemical agents; and whitening toothpaste with abrasive, chemical, and bleaching agents). Brushing and application of whitening gel were performed for 14 days. Surface microhardness (SMH), surface roughness (Ra), and color (ΔL^*, Δa^*, Δb, ΔE^*_{ab}, and ΔE_{00}) were analyzed. The Ra and SMH data were analyzed using mixed generalized linear models for repeated measures, while the color results were assessed using the Kruskal-Wallis and Dunn tests.
Results: Between the initial and final time points, all groups demonstrated significant increases in Ra and reductions in SMH. No significant differences were found between groups for SMH at the final time point, at which all groups differed from the distilled water group. Conventional toothpaste exhibited the lowest Ra, while whitening toothpaste with abrasive agent had the highest value. No significant differences were observed in ΔL^*, Δa^*, and Δb.
Conclusions: While toothpaste composition did not affect the color stability and microhardness of resin composite, combining toothbrushing with whitening toothpaste and at-home bleaching enhanced the change in Ra.

Keywords: Carbamide peroxide; Composite resins; Toothpaste

INTRODUCTION

At-home dental bleaching is a demonstrably effective method that is less expensive than in-office treatments and offers the convenience of home application. These benefits have led to its popularity in the field of cosmetic dentistry [1]. Hydrogen peroxide, the active ingredient in whitening agents, can be applied directly to the tooth surface or produced through the chemical reaction of carbamide peroxide [2].

Author Contributions
Conceptualization: Barbosa CM; Ferraz LN. Data curation: Barbosa CM; Ferraz LN. Formal analysis: Barbosa CM, Ferraz LN, Scatolin RS, Vieira-Junior WF, Tanaka MH. Funding acquisition: Barbosa CM. Investigation: Barbosa CM, Ferraz LN, Scatolin RS, Vieira-Junior WF, Tanaka MH. Methodology: Barbosa CM, Ferraz LN, Scatolin RS, Vieira-Junior WF, Tanaka MH. Project administration: Barbosa CM; Ferraz LN. Resources: Barbosa CM. Software: Barbosa CM, Ferraz LN, Scatolin RS, Vieira-Junior WF, Tanaka MH. Supervision: Barbosa CM. Validation: Barbosa CM, Ferraz LN, Scatolin RS, Vieira-Junior WF, Tanaka MH. Visualization: Barbosa CM, Ferraz LN, Scatolin RS, Vieira-Junior WF, Tanaka MH. Writing - original draft: Barbosa CM, Ferraz LN. Writing - review & editing: Barbosa CM, Ferraz LN, Scatolin RS, Vieira-Junior WF, Tanaka MH.

ORCID iDs
Carolina Meneghin Barbosa
https://orcid.org/0000-0003-3223-3952
Renata Siqueira Scatolin
https://orcid.org/0000-0003-4890-8096
Waldemir Francisco Vieira-Junior
https://orcid.org/0000-0001-8226-3100
Marcia Hiromi Tanaka
https://orcid.org/0000-0002-6594-2301
Laura Nobre Ferraz
https://orcid.org/0000-0002-6234-8913

In patients with direct restorations who perform at-home bleaching, the bleaching gel and restorative material are in prolonged contact, which may lead to interactions between them. Research has indicated that tooth bleaching can have negative impacts on the physical and chemical properties of composite resins, including increased surface roughness (Ra), decreased hardness, and alterations in color and opacity [3-6]. Moreover, during at-home bleaching, the composite resin not only interacts with the bleaching gel, but also is frequently exposed to other substances, such as toothpaste. This can further alter its properties and surface characteristics.

Tooth brushing is the most common oral hygiene practice used to prevent dental caries [7]. The cleaning process is primarily facilitated by abrasive particles, which are insoluble minerals incorporated to disrupt the bacterial biofilm and eliminate microorganisms and stains from tooth surfaces [8-11]. Consequently, the abrasion from brushing can generate wear on restorative materials, which in turn can lead to increased Ra [12-18].

Whitening toothpastes contain the same fundamental ingredients as non-whitening toothpastes [19]. The difference in their composition is due to the inclusion of a whitening agent, which can be abrasive, chemical, or optical [20]. Studies have shown that whitening toothpastes can reduce hardness and increase the Ra of composite resins [21-23]. Therefore, it is worthwhile to explore the impact of whitening toothpastes, which patients may use for oral hygiene during bleaching treatment, on composite resin during at-home bleaching procedures with 10% carbamide peroxide. Additionally, given that bleaching can induce structural alterations in composite resins, it would be valuable to determine whether the use of whitening toothpastes could potentially amplify these changes.

The objective of this *in vitro* study was to examine the impact of various whitening toothpastes on composite resin during at-home bleaching using 10% carbamide peroxide. This was achieved by assessing the surface microhardness (SMH), Ra, and color of the composite resin. The null hypotheses tested were as follows: 1) the application of whitening toothpastes during at-home bleaching with 10% carbamide peroxide would not affect the SMH of the composite resin; 2) the application of whitening toothpastes during at-home bleaching with 10% carbamide peroxide would not alter the Ra of the composite resin; and 3) the application of whitening toothpastes during at-home bleaching with 10% carbamide peroxide would not change the color of the composite resin.

MATERIALS AND METHODS

Experimental design

All groups underwent bleaching. These groups differed in the type of toothpaste used. The factors analyzed included toothpaste, for which 5 options with varying active agents were tested. These were distilled water (serving as the control group), conventional toothpaste (Colgate Total 12 Clean Mint; Colgate-Palmolive Company, New York, NY, USA), whitening toothpaste with abrasive agents (Colgate Luminous White Brilliant; Colgate-Palmolive Company), whitening toothpaste with both abrasive and chemical agents (Colgate Luminous White Instant; Colgate-Palmolive Company), and whitening toothpaste with abrasive, chemical, and bleaching agents (Colgate Luminous White Expert; Colgate-Palmolive Company). The specific composition of each toothpaste is detailed in **Table 1**. Another factor was time; this was studied in relation to Ra and SMH, both initially and at the end of the study. The SMH, Ra, and color (ΔL^*, Δa^*, Δb^*, ΔE^*_{ab}, and ΔE_{00}) were analyzed.

Table 1. Composition of toothpastes used in this study according to the manufacturers' information

Product	Manufacturer	Composition	Bleaching agent
Colgate Total 12 Clean Mint	Colgate - Palmolive Industrial LTDA, São Bernardo do Campo, SP	1,450 ppm sodium fluoride, glycerin/glycerin, water, hydrated silica, sodium lauryl sulfate, arginine, flavor, cellulose gum, zinc oxide, poloxamer 407, tetrasodium pyrophosphate, zinc citrate, benzyl alcohol, xanthan gum, cocamidopropyl betaine, sodium saccharin, phosphoric acid, sucralose, titanium dioxide (CI 77891).	-
Colgate Luminous White Brilliant	Colgate - Palmolive Industrial LTDA, São Bernardo do Campo, SP	1,450 ppm sodium fluoride, water, sorbitol, hydrated silica, PEG-12, sodium lauryl sulfate, flavor, cellulose gum, potassium hydroxide, tetrasodium pyrophosphate, phosphoric acid, cocamidopropyl betaine, benzyl alcohol, sodium saccharin, CI 77891/ dioxide of titanium (CI 77891), dipentene.	Abrasive agent
Colgate Luminous White Instant	Colgate - Palmolive Industrial LTDA, São Bernardo do Campo, SP	1,100 ppm of sodium fluoride, water, hydrated silica, sorbitol, glycerin, PEG-12, pentasodium triphosphate, tetrapotassium pyrophosphate, sodium lauryl sulfate, flavor, cellulose gum, cocamidopropyl betaine, sodium saccharin, xanthan gum, sodium fluoride, sodium hydroxide, hydroxypropyl methylcellulose, propylene glycol, polysorbate 80, mica, CI 74160, CI 77891, CI 73360, CI 17200, CI 42051, eugenol.	Abrasive and chemical agents
Colgate Luminous White Expert	Colgate - Palmolive Industrial LTDA, São Bernardo do Campo, SP	1,000 ppm sodium monofluorophosphate, hydrogen peroxide 2%, sodium monofluorophosphate 0.76%, propylene glycol, calcium pyrophosphate, PVP-hydrogen peroxide, PEG/PPG/16/copolymer 66, PEG-12, glycerin, aroma, sodium lauryl sulfate, silica, PVP, tetrasodium pyrophosphate, sodium saccharin, sodium monofluorophosphate, disodium pyrophosphate, sucralose, BHT, eugenol.	Abrasive, chemical, and bleaching agents

ppm, parts per million; PEG, polyethylene glycol; PVP, polyvinylpyrrolidone; PPG, polypropylene glycol; BHT, butylated hydroxytoluene.

Sample preparation

A total of 120 cylindrical samples of microhybrid composite resin (Filtek Z250; 3M ESPE, St. Paul, MN, USA) in shade B1 were prepared. The samples were allocated based on the types of analyses to be conducted, as the indentation caused by the microhardness analysis could potentially affect the roughness reading, which is a contact analysis. Therefore, 60 samples, each 7 mm in diameter and 2 mm thick, were designated for the color and roughness analyses. The remaining 60 samples, each 3 mm in diameter and 2 mm thick, were reserved for surface microhardness analysis.

The composite resin was placed into the Teflon matrix in a single increment. A polyester strip and a glass slide were then placed on top, under a 500 g weight for a duration of 30 seconds. The samples were subsequently exposed to a diode-emitting curing light (Valo Ultradent Products Inc., South Jordan, UT, USA), for 20 seconds, using the standard power setting of 1,000 mW/cm^2 in accordance with the manufacturer's recommendations. Following this, the samples were stored in distilled water at a temperature of 37°C and a relative humidity of 100% for 24 hours.

Next, the surface of each sample was polished using a polishing machine (APL 4; Arotec, Cotia, SP, Brazil) for 1 minute, employing 600-, 1,200-, and 4,000-grit silicon carbide sanding discs (Buehler Ltd., Lake Bluff, IL, USA). The polishing process was completed using felt discs (TCT, TWI; Arotec) in combination with diamond pastes (3½ and ¼ µm). Between each round of polishing with abrasive paper and felt, the samples were cleaned with deionized water in an ultrasound bath for 5 minutes (Marconi, Piracicaba, SP, Brazil) to eliminate debris. Ultimately, the surfaces of the composite resin samples were shielded with an acid-resistant varnish (Risqué Colorless; Taboão da 8 Serra, SP, Brazil), leaving only the top surface exposed to treatment. As a result, the treatments were confined to a single composite resin surface, mirroring the conditions found in the oral environment. Subsequently, the samples were divided into 5 groups (n = 12), with each group corresponding to the type of toothpaste used. The number of samples was determined based on prior studies found in the literature [24].

Brushing with toothpastes and use of at-home bleaching products

The processes associated with brushing and applying the whitening gel were conducted over a 14-day period. Prior to and following the at-home bleaching, the samples were brushed with toothpastes using an electric toothbrush equipped with a pressure sensor (Oral-B PRO 2000; Procter & Gamble, Cincinnati, OH, USA) [25]. The brush head was consistent across all groups (Precision Clean refill; Procter & Gamble). Moreover, a separate brush head was utilized for each group to prevent any potential interactions between the different types of toothpaste.

Each toothpaste slurry was prepared using a ratio of 3 mL of distilled water to 1 g of toothpaste. The toothpastes were weighed using a precision scale (BG200; Gehaka, São Paulo, SP, Brazil) and then mixed with distilled water until a uniform mixture was achieved immediately prior to use. The samples were secured in an acrylic sample holder, submerged in the slurry for 2 minutes, and brushed for 15 seconds during this period [26]. This methodology was selected to closely mimic real-world clinical conditions, as toothbrushing is typically performed for a total of 2 minutes. Within this timeframe, all tooth surfaces should be brushed. Consequently, the brush is estimated to be in contact with each tooth surface for approximately 15 seconds, which justifies the chosen methodology. The toothbrush was equipped with a light sensor that became activated at 2.5 N. A silicone toothbrush support was constructed to ensure that the brush head remained parallel to the surface throughout the brushing process [26,27]. The same operator conducted the brushing procedures for all groups [28]. The operator rested a hand on the toothbrush to ensure full contact with the silicone device, thereby preventing any movement. The toothbrush was activated without altering the pressure or making any additional manual movements for 15 seconds on each specimen. All durations were monitored using a stopwatch, and the brushing procedure was performed under visual supervision. After 2 minutes, the samples were rinsed for 10 seconds and then stored in distilled water.

For the at-home bleaching process, we utilized a 10% carbamide peroxide gel (Whiteness Perfect 10%; FGM, Joinville, SC, Brazil). The bleaching gel was applied to each sample surface, and following application, the samples were stored at a temperature of 37°C ± 2°C for 4 hours to mimic the oral environment. After each application, the bleaching gel was carefully removed from the surface using flexible cotton swabs. Subsequently, the samples were thoroughly rinsed for 1 minute to ensure complete removal of the gel from their surfaces, preparing them for the next round of brushing.

Color analyses

Color analyses were conducted at the beginning and end of the experiment. To standardize the ambient light during the measurement process, the samples were placed in a Teflon device within a light booth (GTI Mini Matcher MM1e; GTI Graphic Technology, Newburgh, NY, USA). The color readings of the samples were taken using a previously calibrated spectrophotometer (Konica Minolta CM-700d spectrophotometer; Konica Minolta Investment, Shanghai, China) in accordance with the manufacturer's instructions. The readings were quantified using the laboratory system of the Commission Internationale de L'Eclairage (CIE), which uses 3 coordinates: L* (Luminosity, ranging from 0 = Black to 100 = White), a* (Ranging from −axis = Green to +a = Red), and b* (Ranging from axis − b = Blue to axis + b = Yellow). For each sample, 3 readings were taken at each time interval, and the mean was calculated to obtain a value for each coordinate. The color change was determined by calculating the variations in L* ($\Delta L = L^*_{final} - L^*_{initial}$), a* ($\Delta a = a^*_{final} - a^*_{initial}$), and b* ($\Delta b = b^*_{final} - b^*_{initial}$). The general color change was calculated using the following equation: $\Delta E_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$. The ΔE_{00} value was calculated in accordance with the ΔE_{00} equation [29].

https://doi.org/10.5395/rde.2023.48.e26

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right)\right]^{1/2}$$

To analyze the findings, we considered a perceptibility threshold of 50:50% for an ΔE^*_{ab} of 1.2, as well as an acceptability threshold of 50:50% for an ΔE^*_{ab} of 2.7. For ΔE_{00}, the corresponding values were 0.8 and 1.8, respectively [30].

Ra

The surface roughness was assessed at both initial and final time points. This roughness was gauged using a contact profilometer (SJ 301; Mitutoyo Corporation, Kawasaki, Japan). On the surface of each sample, measurements were taken in 3 equidistant directions at each time interval. These measurements were conducted with a cut-off point of 0.25 mm, a reading length of 1.25 mm, and a speed of 0.1 mm/s. The average of the obtained values was computed, and a single Ra value per sample was considered.

SMH

The analysis of surface microhardness was conducted at both initial and final time points. We used a Knoop indenter in a microhardness tester (HMV-2000; Shimadzu, Tokyo, Japan), applying a load of 25 g for 5 seconds. On each sample, 5 indentations were made, each spaced 100 µm apart. The average of these measurements was then calculated to determine the Knoop hardness number.

Statistical analysis

Initially, we conducted descriptive and exploratory data analyses. We analyzed the data on microhardness and roughness using mixed generalized linear models for repeated measures over time. The color results (ΔL^*, Δa^*, Δb^*, ΔE^*_{ab}, and ΔE_{00}) did not conform to a known distribution, so we used the Kruskal-Wallis and Dunn tests for analysis. We performed all analyses using the R program (R Core Team, 2021; R Foundation for Statistical Computing, Vienna, Austria), with the significance level set at 5%.

RESULTS

The findings of the surface microhardness analyses are detailed in **Table 2**. A significant decrease in microhardness was observed across all groups when comparing the initial and final time points ($p < 0.05$). However, between-group comparisons showed no statistically significant differences at the initial and final time intervals.

Table 2. Knoop microhardness as a function of group and time

Group	Time*	
	Initial	Final
Distilled water	100.45 ± 7.71^{Aa}	76.08 ± 4.55^{Ba}
Conventional toothpaste	105.27 ± 7.16^{Aa}	77.46 ± 5.45^{Ba}
Whitening toothpaste with abrasive agents	101.07 ± 5.45^{Aa}	78.47 ± 4.80^{Ba}
Whitening toothpaste with abrasive and chemical agents	104.67 ± 4.97^{Aa}	76.02 ± 4.72^{Ba}
Whitening toothpaste with abrasive, chemical, and bleaching agents	105.18 ± 4.64^{Aa}	77.21 ± 5.10^{Ba}

Values are presented as mean ± standard deviation.
*Initial = baseline; Final = after 14 days of bleaching associated with brushing. Different letters (uppercase horizontally and lowercase vertically) indicate statistically significant differences ($p \leq 0.05$). p(group) = 0.4358; p(time) < 0.0001; p(interaction) = 0.3779.

https://doi.org/10.5395/rde.2023.48.e26

Table 3. Roughness as a function of group and time

Group	Time*	
	Initial	Final
Distilled water	0.22 ± 0.01[Ba]	0.30 ± 0.01[Ae]
Conventional toothpaste	0.23 ± 0.01[Ba]	0.40 ± 0.01[Ad]
Whitening toothpaste with abrasive agents	0.23 ± 0.01[Ba]	0.50 ± 0.01[Aa]
Whitening toothpaste with abrasive and chemical agents	0.23 ± 0.01[Ba]	0.46 ± 0.01[Ab]
Whitening toothpaste with abrasive, chemical, and bleaching agents	0.23 ± 0.01[Ba]	0.43 ± 0.01[Ac]

Values are presented as mean ± standard deviation.
*Initial = baseline; Final = after 14 days of bleaching associated with brushing. Different letters (uppercase horizontally and lowercase vertically) indicate statistically significant differences ($p \leq 0.05$). p(group) < 0.0001; p(time) < 0.0001; p(interaction) < 0.0001.

Table 4. ΔL*, Δa*, and Δb* as a function of group

Group	DL*	Da*	Db*
Distilled water	0.29 ± 0.83[a]	0.13 ± 0.22[ab]	−0.86 ± 0.41[b]
Conventional toothpaste	0.22 ± 0.21[a]	0.15 ± 0.14[ab]	−0.62 ± 0.27[ab]
Whitening toothpaste with abrasive agents	−0.26 ± 0.56[a]	0.32 ± 0.15[a]	−0.57 ± 0.38[ab]
Whitening toothpaste with abrasive and chemical agents	0.00 ± 0.24[a]	0.00 ± 0.16[b]	−0.60 ± 0.29[ab]
Whitening toothpaste with abrasive, chemical, and bleaching agents	0.18 ± 0.33[a]	0.24 ± 0.10[a]	−0.32 ± 0.19[a]

Values are presented as mean ± standard deviation.
The multiple comparison test (Dunn) did not detect significant differences between groups ($p > 0.05$). Distinct vertical letters indicate statistically significant differences ($p < 0.05$). p(group)ΔL* = 0.05, p(group)Δa* = 0.009, p(group)Δb* = 0.0119.

Table 3 displays the results of the surface roughness analyses. Regardless of the type of toothpaste used, all groups demonstrated a significant increase in roughness when comparing the initial and final time intervals ($p < 0.0001$). No significant difference was found among the groups at baseline. However, at the final time point, all groups differed significantly from each other. Distilled water was associated with the lowest roughness values, followed by conventional toothpaste. Whitening toothpaste with abrasive agents exhibited the highest roughness value of the groups.

Table 4 presents the results of the ΔL, Δa, and Δb analyses. No statistically significant differences in ΔL were observed across groups ($p > 0.05$). Regarding Δa, none of the toothpastes exhibited a statistical difference relative to the distilled water group. Whitening toothpaste with abrasive agents showed no significant difference from whitening toothpaste with abrasive, chemical, and bleaching agents ($p > 0.05$). However, these treatments displayed a statistical difference when compared to whitening toothpaste with abrasive and chemical agents ($p < 0.05$). For Δb, conventional toothpaste, whitening toothpaste with abrasive agents, and whitening toothpaste with abrasive and chemical agents showed no statistical differences when compared to the control group (distilled water) ($p > 0.05$). Treatment with whitening toothpaste with abrasive, chemical, and bleaching agents showed a statistical difference from the control group ($p < 0.05$), but no difference was observed relative to the other toothpaste groups evaluated ($p > 0.05$).

Table 5 presents the results of the ΔE^*_{ab} and ΔE_{00} analyses. For ΔE^*_{ab}, we found no statistical difference between conventional toothpaste and whitening toothpaste with abrasive agents when compared to the control group (distilled water). However, the results of the whitening toothpaste with abrasive and chemical agents, along with those of the whitening toothpaste with abrasive, chemical, and bleaching agents, differed significantly from the control group findings ($p < 0.05$). Despite this, these groups exhibited no statistical difference relative to the other toothpaste groups analyzed.

Table 5. ΔE^*_{ab} and ΔE_{00} as a function of group

Group	DE^*_{ab}	DE_{00}
Distilled water	1.22 ± 0.45[a]	0.87 ± 0.29[a]
Conventional toothpaste	0.73 ± 0.23[ab]	0.54 ± 0.09[ab]
Whitening toothpaste with abrasive agents	0.86 ± 0.46[ab]	0.71 ± 0.29[a]
Whitening toothpaste with abrasive and chemical agents	0.66 ± 0.29[b]	0.45 ± 0.17[b]
Whitening toothpaste with abrasive, chemical, and bleaching agents	0.56 ± 0.16[b]	0.47 ± 0.13[b]
p	0.0005	< 0.0001

Values are presented as mean ± standard deviation.
Distinct vertical letters indicate statistically significant differences. p(group)ΔE^*_{ab} = 0.0005, p(group)ΔE_{00} < 0.0001.

For ΔE_{00}, we found no statistically significant difference between conventional toothpaste and whitening toothpaste with abrasive agents, relative to the control group (distilled water). However, the whitening toothpaste with both abrasive and chemical agents, as well as the whitening toothpaste with abrasive, chemical, and bleaching agents, showed a statistically significant difference when compared to the control and the whitening toothpaste with abrasive agents. Interestingly, no statistically significant difference was observed between these groups and the conventional toothpaste group.

DISCUSSION

The first hypothesis tested in this study was confirmed, as none of the evaluated toothpastes induced changes in the surface microhardness of the composite resin during at-home bleaching with 10% carbamide peroxide. Despite no toothpaste differing significantly from the distilled water group, a decrease in microhardness was noted across all groups when comparing the initial and final time intervals. However, no statistically significant difference was found between them. This finding aligns with previous studies and can be explained by the impact of hydrogen peroxide on the composite resin matrix [4,7]. The 10% carbamide peroxide contains between 3.0 and 3.5% hydrogen peroxide [31]. Furthermore, hydrogen peroxide can generate free radicals due to its high oxidation and reduction capacity, which involves the transfer of electrons between atoms [32]. This process can degrade the resin matrix and fracture the polymeric chains of composite resins [32,33]. Given these results, it can be inferred that the effect of at-home bleaching with 10% carbamide peroxide surpasses any potential effects of the toothpastes evaluated in this study. The concentration of hydrogen peroxide in toothpaste is 2%, a level that is inconsequential for whitening [34].

In addition to hydrogen peroxide, the thickener present in the bleaching gel composition may have also influenced the surface microhardness results observed in this study [5]. The bleaching gel utilized in this research contained Carbopol as its thickening agent. It has been noted that bleaching gels containing Carbopol may lead to lower surface microhardness values for the composite resin, relative to those without Carbopol [5]. Carbopol, an ingredient with an acidic pH and a high ionic capacity to interact with resin monomers, could have also played a role in the degradation of the composite resin, thereby contributing to changes in surface microhardness [5,9,35].

The surface roughness results obtained in this study may have been influenced by the hydrogen peroxide and Carbopol thickener. All groups demonstrated an increase in surface roughness following the application of 10% carbamide peroxide and toothpastes on microhybrid composite resin. The brushing process could have further contributed to the increase in surface roughness of the microhybrid composite resin, as all groups, including

https://doi.org/10.5395/rde.2023.48.e26

the control group that was brushed with distilled water, underwent the brushing protocol. Previous studies have indicated that when brush bristles are applied to composite resin and rubbed, they create spaces that enhance the surface roughness of the microhybrid composite resin [12,17,18]. This is likely due to the wearing out of its organic component by the abrasion produced by the brush [12].

Upon comparing the roughness across groups, we found significant differences between the evaluated toothpastes and the control group. This finding led us to reject the second hypothesis examined in this study. The differences observed between the groups could be associated with the composition of the toothpastes. The use of whitening toothpaste with abrasive agents was associated with the greatest increase in surface roughness. This toothpaste contains hydrated silica and titanium dioxide. Research has indicated that hydrated silica is a highly effective abrasive, promoting a greater increase in roughness compared to other abrasives [36]. Whitening toothpastes typically contain a higher quantity of abrasives in their formulation compared to conventional non-whitening toothpastes [20].

Whitening toothpaste that contains both abrasive and chemical agents includes not only hydrated silica in its composition, but also pentasodium triphosphate, tetrapotassium pyrophosphate, and mica abrasives. Despite having a higher quantity of abrasives, this toothpaste resulted in less surface roughness compared to whitening toothpaste containing only abrasive agents. This outcome may be linked to the specific type of abrasive used. The existing literature indicates that the size, hardness, shape, and quantity of the abrasive particles can influence the abrasive action of toothpastes [37,38]. One study found that the larger the abrasive particle, the greater the toothpaste's abrasive capacity [39]. Additionally, particles of different shapes have varying abrasive indices [40]. The abrasiveness of a toothpaste is tied to the physical characteristics of its abrasive components. For instance, when fine and regular particles of silica are used, the toothpaste does not exhibit a high abrasive capacity. However, when the silica particles are coarse and irregular, the toothpaste demonstrates higher levels of abrasiveness [41]. This is because larger and irregular particles cause more wear on the resin matrix, which exposes the filler particles and subsequently increases the surface roughness of the microhybrid composite resin [10].

Whitening toothpaste, which contains abrasive, chemical, and bleaching agents, includes abrasive calcium pyrophosphate, silica, tetrasodium pyrophosphate, and disodium pyrophosphate. These ingredients may have contributed to changes in surface roughness values. The toothpaste also contains 2% hydrogen peroxide. Despite the potential for hydrogen peroxide to increase the roughness of composite resin, the 2% concentration in this toothpaste did not seem to exacerbate surface roughness [32]. In fact, it demonstrated the lowest roughness values among the whitening toothpastes evaluated. This could be due to the brief exposure of the composite resin to the toothpaste, which was used for a total of 2 minutes twice daily over a 14-day period. Additionally, hydrogen peroxide is highly reactive and may have decomposed within the toothpaste tube, rendering it ineffective at the time of use. For tooth bleaching, hydrogen peroxide must remain on the tooth surface for a duration specified by the manufacturer's instructions to allow for oxidation of the organic matrix [31].

The toothpaste that exhibited the least variation was the conventional, non-whitening type. These findings align with previous studies, which similarly noted that non-whitening toothpastes demonstrated a smaller increase in roughness compared to their whitening counterparts [8,37].

https://doi.org/10.5395/rde.2023.48.e26

The color of the composite resin samples was assessed using the CIE L*a*b* laboratory system. This system utilizes 3 coordinates: L* (indicating Luminosity, where 0 = Black to 100 = White), a* (Ranging from −a = Green to +a = Red), and b* (Ranging from −b = Blue to +b = Yellow) [42]. These coordinates define an object's color within a 3-dimensional color space, as analyzed with On-Color QC Lite software (Konica Minolta, Tokyo, Japan). The terms ΔE^{*}_{ab} and ΔE_{00} represent the overall color variation [43]. In terms of ΔL* and Δa*, no statistically significant differences were observed between the groups. Δb* exhibited differences when compared to the control group, but no significant differences were found when compared to the other toothpastes evaluated, which were similar to the control group. However, regarding ΔE^{*}_{ab} and ΔE_{00}, the whitening toothpastes containing abrasive and chemical agents, as well as those with abrasive, chemical, and bleaching agents, differed from the control group but resembled the conventional toothpaste, which lacks a whitening agent. This finding led to the rejection of the third hypothesis examined in this study. Despite this, the mean total color change values (ΔE^{*}_{ab}, ΔE_{00}) were lower for the whitening toothpaste groups compared to the control group, indicating that the toothpastes did not significantly alter color. Moreover, all groups evaluated had values lower than the standard values suggested for clinical acceptability of color differences, which are 4.2 units or 3.3 units [43,44]. According to Paravina *et al.* [30], the 50:50% perceptibility threshold for ΔE^{*}_{ab} is 1.2, while the 50:50% acceptability threshold for ΔE^{*}_{ab} is 2.7. For ΔE_{00}, the corresponding values are 0.8 and 1.8, respectively. This means that the values found in this study were either far below or at the threshold of the values considered in the literature.

An important observation from the color analyses was related to the role of titanium dioxide in both conventional and whitening toothpastes that contain abrasive agents. Titanium dioxide, a white pigment that enhances the whiteness and opacity of products, is found in the composition of certain toothpastes in powdered form [45]. As noted earlier, the abrasives in whitening toothpastes can cause abrasion of the restorative material, allowing the titanium dioxide to infiltrate the resulting irregularities [46]. However, the titanium dioxide in both the conventional and whitening toothpastes with abrasive agents did not affect the color of the composite resin, as no statistical difference was found in the color analysis.

While the findings of this study are noteworthy, it is crucial to consider that they may not transfer directly to the clinical setting due to several key individual factors related to toothbrushing. These factors include the type of brush used (specifically, the hardness and characteristics of the brush bristles), the force applied during brushing, and the frequency of brushing. Additionally, the market offers a vast array of composite resins with varying compositions. These variables complicate the task of generalizing the results to a clinical setting, but they can help predict typical clinical scenarios. Nonetheless, additional studies could prove beneficial in this context.

CONCLUSIONS

While toothpaste composition did not affect the color stability or microhardness of resin composite, combining toothbrushing with whitening toothpaste and at-home bleaching increased the change in Ra.

ACKNOWLEDGEMENTS

We would like to express our gratitude to the Hermínio Ometto Foundation and the University of Araras, Brazil. We are also grateful to the Dental Clinic and Oral Medicine Clinic (Orocentro) of the Piracicaba Dental School at the University of Campinas, Brazil, for their invaluable support throughout this study. We deeply appreciate all of the volunteers who participated in this study.

REFERENCES

1. de Geus JL, Wambier LM, Kossatz S, Loguercio AD, Reis A. At-home vs in-office bleaching: a systematic review and meta-analysis. Oper Dent 2016;41:341-356.
PUBMED | CROSSREF
2. Eimar H, Siciliano R, Abdallah MN, Nader SA, Amin WM, Martinez PP, Celemin A, Cerruti M, Tamimi F. Hydrogen peroxide whitens teeth by oxidizing the organic structure. J Dent 2012;40(Supplement 2):e25-e33.
PUBMED | CROSSREF
3. Hafez R, Ahmed D, Yousry M, El-Badrawy W, El-Mowafy O. Effect of in-office bleaching on color and surface roughness of composite restoratives. Eur J Dent 2010;4:118-127.
PUBMED | CROSSREF
4. Li Y. Safety controversies in tooth bleaching. Dent Clin North Am 2011;55:255-263.
PUBMED | CROSSREF
5. Gouveia TH, Públio JD, Ambrosano GM, Paulillo LA, Aguiar FH, Lima DA. Effect of at-home bleaching with different thickeners and aging on physical properties of a nanocomposite. Eur J Dent 2016;10:82-91.
PUBMED | CROSSREF
6. Correia Vieira A, Silva de Oliveira MC, Castro Vieira Andrade A, Leite MF, Gonçalves FL, Rocha e Silva J. The effects of over-the-counter bleaching products on the surface of nanofilled composite. Arq Odontol 2020;56:1120471.
CROSSREF
7. Melo CF, Manfroi FB, Spohr AM. Microhardness and roughness of enamel bleached with 10% carbamide peroxide and brushed with different toothpastes: an in situ study. J Int Oral Health 2014;6:18-24.
PUBMED
8. Worschech CC, Rodrigues JA, Martins LR, Ambrosano GM. *In vitro* evaluation of human dental enamel surface roughness bleached with 35% carbamide peroxide and submitted to abrasive dentifrice brushing. Pesqui Odontol Bras 2003;17:342-348.
PUBMED | CROSSREF
9. Çakmakçioglu Ö, Yilmaz P, Topba BF. Clinical evaluation of whitening effect of whitening toothpastes: a pilot study. Oral Health Dent Manag Black Sea Ctries 2009;8:6-13.
10. Barbieri GM, Mota EG, Rodrigues-Junior SA, Burnett LH Jr. Effect of whitening dentifrices on the surface roughness of commercial composites. J Esthet Restor Dent 2011;23:338-345.
PUBMED | CROSSREF
11. Soares de Queiroz A, Rodrigues dos Santos I, da Mota Martins V, Maria de Oliveira Andrade M, Dietrich L, Nascimento F, Alves dos Reis T. The influence of toothpaste on the abrasivity of dental structure: a narrative review. Res Soc Dev 2021;10:e210101421985.
CROSSREF
12. Daud A, Adams AJ, Shawkat A, Gray G, Wilson NH, Lynch CD, Blum IR. Effects of toothbrushing on surface characteristics of microhybrid and nanofilled resin composites following different finishing and polishing procedures. J Dent 2020;99:103376.
PUBMED | CROSSREF
13. Wang L, Garcia FC, Amarante de Araújo P, Franco EB, Mondelli RF. Wear resistance of packable resin composites after simulated toothbrushing test. J Esthet Restor Dent 2004;16:303-314.
PUBMED | CROSSREF
14. Heintze SD, Forjanic M, Ohmiti K, Rousson V. Surface deterioration of dental materials after simulated toothbrushing in relation to brushing time and load. Dent Mater 2010;26:306-319.
PUBMED | CROSSREF

15. Turgut S, Bagis B, Ayaz EA, Ulusoy KU, Altintas SH, Korkmaz FM, Bagis N. Discoloration of provisional restorations after oral rinses. Int J Med Sci 2013;10:1503-1509.
PUBMED | CROSSREF

16. Bernardon JK, Vieira Martins M, Branco Rauber G, Monteiro Junior S, Baratieri LN. Clinical evaluation of different desensitizing agents in home-bleaching gels. J Prosthet Dent 2016;115:692-696.
PUBMED | CROSSREF

17. Heintze SD, Forjanic M. Surface roughness of different dental materials before and after simulated toothbrushing *in vitro*. Oper Dent 2005;30:617-626.
PUBMED

18. Oliveira GU, Mondelli RF, Charantola Rodrigues M, Franco EB, Ishikiriama SK, Wang L. Impact of filler size and distribution on roughness and wear of composite resin after simulated toothbrushing. J Appl Oral Sci 2012;20:510-516.
PUBMED | CROSSREF

19. Joiner A. Whitening toothpastes: a review of the literature. J Dent 2010;38(Supplement 2):e17-e24.
PUBMED | CROSSREF

20. Joiner A, Philpotts CJ, Alonso C, Ashcroft AT, Sygrove NJ. A novel optical approach to achieving tooth whitening. J Dent 2008;36(Supplement 1):S8-S14.
PUBMED | CROSSREF

21. Khamverdi Z, Kasraie S, Rezaei-Soufi L, Jebeli S. Comparison of the effects of two whitening toothpastes on microhardness of the enamel and a microhybride composite resin: an *in vitro* study. J Dent (Tehran) 2010;7:139-145.
PUBMED

22. Nainan MT, Balan AK, Sharma R, Thomas SS, Deveerappa SB. The comparison of the effects of different whitening toothpastes on the micro hardness of a nano hybrid composite resin. J Conserv Dent 2014;17:550-554.
PUBMED | CROSSREF

23. Dos Santos JH, Silva NL, Gomes MG, Paschoal MA, Gomes IA. Whitening toothpastes effect on nanoparticle resin composite roughness after a brushing challenge: An *in vitro* study. J Clin Exp Dent 2019;11:e334-e339.
PUBMED | CROSSREF

24. Vieira I, Ferraz LN, Vieira Junior WF, Dias CT, Lima DA. Effect of at-home bleaching gels with different thickeners on the physical properties of a composite resin without bisphenol A. J Esthet Restor Dent 2022;34:969-977.
PUBMED | CROSSREF

25. Schlueter N, Klimek J, Ganss C. Effect of a chitosan additive to a Sn^{2+}-containing toothpaste on its anti-erosive/anti-abrasive efficacy--a controlled randomised in situ trial. Clin Oral Investig 2014;18:107-115.
PUBMED | CROSSREF

26. Comar LP, Gomes MF, Ito N, Salomão PA, Grizzo LT, Magalhães AC. Effect of NaF, SnF_2, and TiF_4 toothpastes on bovine enamel and dentin erosion-abrasion *in vitro*. Int J Dent 2012;2012:134350.
PUBMED | CROSSREF

27. Moron BM, Miyazaki SS, Ito N, Wiegand A, Vilhena F, Buzalaf MA, Magalhães AC. Impact of different fluoride concentrations and pH of dentifrices on tooth erosion/abrasion *in vitro*. Aust Dent J 2013;58:106-111.
PUBMED | CROSSREF

28. Pini NI, Schlueter N, Sundfeld D, Semper Hogg W, Santos-Silva AR, Lopes MA, Aguiar FH, Lovadino JR, Lima DA. Efficacy of stannous ions on enamel demineralization under normal and hyposalivatory conditions: a controlled randomized *in situ* pilot trial. Caries Res 2017;51:543-553.
PUBMED | CROSSREF

29. Luo MR, Cui G, Rigg B. The development of the CIE 2000 colour-difference formula: CIEDE2000. Color Res Appl 2001;269:340-350.
CROSSREF

30. Paravina RD, Ghinea R, Herrera LJ, Bona AD, Igiel C, Linninger M, Sakai M, Takahashi H, Tashkandi E, Perez MM. Color difference thresholds in dentistry. J Esthet Restor Dent 2015;27(Supplement 1):S1-S9.
PUBMED | CROSSREF

31. Kwon SR, Wertz PW. Review of the mechanism of tooth whitening. J Esthet Restor Dent 2015;27:240-257.
PUBMED | CROSSREF

32. Hannig C, Duong S, Becker K, Brunner E, Kahler E, Attin T. Effect of bleaching on subsurface micro-hardness of composite and a polyacid modified composite. Dent Mater 2007;23:198-203.
PUBMED | CROSSREF

33. Bailey SJ, Swift EJ Jr. Effects of home bleaching products on composite resins. Quintessence Int 1992;23:489-494.
PUBMED

34. Silva Oliveira R, Lima MJP, de Jesus Campos E. Ação de dentifrício com peróxido de hidrogênio sobre resina composta nanoparticulada. Rev Cienc Med Biol 2019;18:372-379.
CROSSREF

35. Wu W, McKinney JE. Influence of chemicals on wear of dental composites. J Dent Res 1982;61:1180-1183.
PUBMED | CROSSREF

36. Ferreira MC, Ramos-Jorge ML, Delbem AC, Vieirac RS. Effect of toothpastes with different abrasives on eroded human enamel: an *in situ/ex vivo* study. Open Dent J 2013;7:132-139.
PUBMED | CROSSREF

37. Hilgenberg SP, Pinto SC, Farago PV, Santos FA, Wambier DS. Physical-chemical characteristics of whitening toothpaste and evaluation of its effects on enamel roughness. Braz Oral Res 2011;25:288-294.
PUBMED | CROSSREF

38. Walsh T, Worthington HV, Glenny AM, Marinho VC, Jeroncic A. Fluoride toothpastes of different concentrations for preventing dental caries. Cochrane Database Syst Rev 2019;3:CD007868.
PUBMED | CROSSREF

39. Camargo I, Zoppe C, Saiki M, Marinho VC, Jeroncic A. Evaluation of the precision in the dentifrice abrasivity measurements obtained by a radiotracer method. J Radioanal Nucl Chem 2001;249:487-489.
CROSSREF

40. Davis WB, Winter PJ. Measurement *in vitro* of enamel abrasion by dentifrice. J Dent Res 1976;55:970-975.
PUBMED | CROSSREF

41. Gusmão ES, Melo JAS, Ramos CG, Santos RL, Araújo ACS, Feitosa DS. Aplicabilidade clínica dos dentifrícios. Int J Dent 2003;2:231-235.

42. Khashayar G, Bain PA, Salari S, Dozic A, Kleverlaan CJ, Feilzer AJ. Perceptibility and acceptability thresholds for colour differences in dentistry. J Dent 2014;42:637-644.
PUBMED | CROSSREF

43. Alghazali N, Burnside G, Moallem M, Smith P, Preston A, Jarad FD. Assessment of perceptibility and acceptability of color difference of denture teeth. J Dent 2012;40(Supplement 1):e10-e17.
PUBMED | CROSSREF

44. Um CM, Ruyter IE. Staining of resin-based veneering materials with coffee and tea. Quintessence Int 1991;22:377-386.
PUBMED

45. Frazer L. Titanium dioxide: environmental white knight? Environ Health Perspect 2001;109:A174-A177.
PUBMED | CROSSREF

46. Tostes NE, Baptista NB, Carvalho Júnior OB, Francisconi PAS, Pires HC. Avaliação do desgaste produzido em esmalte por cremes dentais clareadores. Rev Odontol Araçatuba 2009;30:9-13.

https://doi.org/10.5395/rde.2023.48.e26