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Effect of Commercial Mouth Rinses on Physical Properties of Conventional and Bulk-fill Resin Composites

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Clinical Relevance

Mouth rinses are frequently used without the supervision of a dentist; moreover, these products can impact the staining and degradation of resin-based materials, especially in the bulk-fill resin composites.

SUMMARY

Objective: To evaluate the effects of commercial mouth rinses on color, roughness, sorption (SR), and solubility (SL) of resin composites.

Methods and Materials: Disc-shaped specimens (stage I: 6 mm x 2 mm; stage II: 10 mm x 1.5 mm) were made from the following resin composites (n=10): conventional nanofilled (Filtek Z350XT, 3M Oral Care), conventional nanohybrid (Luna, SDI), bulk-fill nanofilled (Filtek One Bulk-Fill, 3M Oral Care), and bulk-fill nanohybrid (Aura Bulk-Fill, SDI) exposed to distilled water (control), blue mouth rinse without alcohol (Colgate Total 12 Clean Mint, Colgate-Palmolive), or blue mouth rinse with alcohol and essential oil (Listerine Tartar Control, Johnson & Johnson). In stage I, tests were performed at the baseline, and after the immersion in solution time points to evaluate coordinates of the CIEL*a*b* system (ΔL^*, Δa^*, Δb^*), general color change (ΔE_{ab}, ΔE_{00}, and ΔSGU), and surface roughness (Ra). In stage II, SR and SL

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were evaluated (ISO 4049:2019) after immersion in the solutions for 7 days. The results were evaluated by generalized linear models (Ra, SR), Kruskal–Wallis, and Dunn tests (color, SL), with $\alpha = 0.05$.

Results: There were no significative differences for Ra between the solutions. Both mouth rinses promoted significantly negative ΔL* (Luna), Δa* (Filtek One Bulk-fill), and Δb* (all materials except conventional nanofilled resin composite). Mouth rinse without alcohol promoted significantly negative Δa* on all resin composites tested. Both mouth rinses promoted higher ΔE_{ab} and ΔE_{00} for bulk-fill resin composites compared to control. Mouth rinse with alcohol caused higher ΔSGU for bulk-fill nanofilled resin composite. It also promoted greater SR in all the resin composites compared with mouth rinse without alcohol and higher SR in nanohybrid resin composites compared with control. Both mouth rinses promoted higher SL values in Luna and differed significantly from control.

Conclusions: The physical properties were manufacturer dependent and mediated by mouth rinses. The mouth rinses promoted color changes in the resin composites, pointing out that bulk-fill resin composites were more affected by these effects, especially when the mouth rinse contained essential oil and alcohol.

INTRODUCTION

Resin composites are light-cured materials widely used for the restoration of anterior and posterior teeth, because of their esthetic and mechanical properties.[1,2] These materials are composed of a resin matrix and silane-treated inorganic fillers[1,2] and are commonly classified according to filler size or monomer type.[1,3,4] Even though the properties of resin composites are adequate for clinical use, the polymerization shrinkage of these materials is still a drawback caused by the conversion of monomers into a polymeric network.[5] Polymerization stress is a multifactorial phenomenon determined by factors such as volumetric shrinkage, viscoelastic behavior, incremental insertion technique, and material reaction kinetics.[6] The oral environment is subject to conditions of chemical and mechanical stress, which can induce defects in the restoration to tooth interface, postoperative sensitivity, and cusp deflection.[7-9]

The incremental insertion technique is an interesting option, because it can reduce polymerization shrinkage-induced stress, by using small resin composite increments of 2 mm.[7,8] However, the long duration of the procedure and the difficulty in allocating the increments in interproximal regions or small cavities represent some of the drawbacks of this technique.[10] New materials have been developed to overcome these difficulties, adopt new ways of minimizing technique-associated failures, and offset the effects caused by polymerization shrinkage-induced stress. One of these materials is bulk-fill resin composite, favored for allowing larger increments (4-5 mm) to be made.[11-13]

Although only few controlled long-term clinical trials have addressed these bulk-fill resin composites, current studies suggest that they are similar to conventional resin composites, in terms of clinical performance.[14-16] Overall, the most important factors contributing to the long-term success of dental restorations include marginal adaptation, wear resistance, fracture strength, and color stability.[17] Color changes suggest material degradation is caused either by extrinsic or intrinsic agents[18] and is an important clinical aspect to be considered when replacing restorations.[19] Extrinsic staining refers to the pigmentation derived from external chromogenic agents. It is caused by the adsorption of pigments that can be internalized and depends on surface roughness (Ra) and the sorption (SR) and solubility (SL) of the material.[18,20] The dynamic of bulk-fill resin pigmentation has not yet been widely investigated, especially regarding the impact of commercial mouth rinses.

Mouth rinses are commonly used on a daily basis and are recommended for different clinical situations. However, these easily and frequently acquired substances are often used without professional supervision.[21] A previous study[22] suggested that 56% of adults aged 25-34 years were mouth-rinse users, and 25.1% of all age groups used mouth rinses daily. Mouth rinses are found on the market mostly as a cosmetic product, purchased without the supervision or recommendation of a dentist. However, it should be borne in mind that the active ingredients and agents in their composition include such elements as alcohol and essential oils, which can trigger chemical and biological actions in tooth tissues and dental materials.[23] Therefore, the greater and more widespread use of these products makes it clinically relevant and indispensable to evaluate the effects of mouth rinses on the properties of resin-based materials. Mouth rinses appear to not cause clinically significant color changes to conventional resin composites,[24] however, there is still a lack of studies that investigate these dynamics, especially for bulk-fill composites. Moreover, an investigation should be made comparing the behavior of bulk-fill resin composites and the performance of conventional resin composites exposed to mouth rinses. This would help gain a better understanding of the properties of these materials, considering the few studies that discuss how different solutions affect the chromatic properties of bulk-fill resins.

Thus, the objective of this *in vitro* study was to evaluate the effects of different commercial mouth rinses containing blue colorant and formulated with or without alcohol, on color stability, Ra, SR, and SL of conventional and bulk-fill resin composites. Three null hypotheses were proposed.

1. The commercial mouth rinses evaluated do not affect the properties of color stability and Ra of resin composites.
2. The commercial mouth rinses evaluated do not affect the properties of SR or SL of the resin composite over time.
3. The bulk-fill resin composites tested do not differ from conventional resin composites exposed to commercial mouth rinses, in regard to the properties evaluated.

METHODS AND MATERIALS

Considering the objective and hypotheses presented, this study was carried out in two stages. In stage I, color properties (ΔL^*, Δa^*, Δb^*, ΔE_{ab}, ΔE_{00}, and ΔSGU) and Ra were evaluated, whereas stage II performed SR and SL analyses after 7 days of immersion in each solution, according to ISO 4049:2019.

Restorative Materials and Solutions

Four types of resin composites (see Table 1) were used: conventional nanofilled (Filtek Z350XT, 3M Oral Care, St Paul, MN, USA), conventional nanohybrid (Luna, SDI, Bayswater, Victoria, Australia), bulk-fill nanofilled (Filtek One Bulk- Fill, 3M Oral Care), and bulk-fill nanohybrid (Aura Bulk-Fill, SDI). Each resin composite group was exposed to different solutions (Table 2): distilled water (control), mouth rinse without alcohol (Color – blue, Colgate Total 12 Clean Mint, Colgate-Palmolive, São Paulo, Brazil), and mouth rinse with alcohol and essential oil (Color – blue, Listerine Tartar Control, Johnson & Johnson, São Paulo, Brazil).

Specimen Preparation

A total of 120 disc-shaped specimens of each resin composite were made for each stage of the study (n=10), all following the same preparation procedure. The resin composites were inserted in a silicone matrix (6 mm x 2 mm for stage I and 10 mm x 1.5 mm for stage II) in a single increment using an insertion spatula (Goldstein XTS flex, Hu-Friedy, Chicago, IL, USA). Then, the material

Table 1: *Composition, Classification, and Manufacturers of Resin Composites*[a]

Resin Composite	Classification	Manufacturer	Composition
Filtek Z350 XT Shade: A1E	Conventional nanofilled	3M Oral Care	Bis-EMA, UDMA, Bis-GMA, TEGDMA, polyethylene glycol dimethacrylate, silane-treated ceramic (60%-80% in weight); silane-treated silica (1%-10% in weight); silane-treated zirconia (1%-5% in weight)
Luna Shade: EA1	Conventional nanohybrid	SDI	Acrylic monomers: UDMA, Bis-EMA, TEGDMA; 7,7,9 (or 7,9,9)-trimethyl 4,13-dioxo-3,14-dioxa-5,12-diazahexadecane1,16-diyl bismethacrylate; 2,2'-ethylenedioxydiethyl dimethacrylate; isopropylidenebis methacrylate (pphenyleneoxyethylene)
Filtek One Bulk Fill Shade: A1	Bulk-fill nanofilled	3M Oral Care	Aromatic urethane dimethacrylate, UDMA, DDDMA, water, silane-treated ceramic (60%-70% in weight); silane-treated silica (1%-10% in weight); silane-treated zirconia (<5% in weight), ytterbium fluoride
Aura Bulk-Fill Shade: BKF (universal)	Bulk-fill nanohybrid	SDI	UDMA, Bis-EMA, Bis-GMA, TEGDMA, amorphous SiO_2, barium aluminosilicate glass, prepolymerized filler particles.

Abbreviations: Bis-EMA, bisphenol-A hexaethoxylated dimethacrylate; UDMA, urethane dimethacrylate; Bis-GMA, bisphenol-A glycidyl methacrylate; TEGDMA, triethylene glycol dimethacrylate; DDDMA, 1,12 dodecanediol dimethacrylate.
[a]Composition information as presented in the Material Safety Data Sheet provided by the manufacturers.

Table 2: *Information of Solutions and Mouth Rinses*[a]

Solution/ Mouth Rinse	Classification	Manufacturer	Composition	Coloring	pH
Distilled water	Control	—	Distilled water	—	7.0
Colgate Total 12 Clean Mint	Mouth rinse without alcohol	Colgate-Palmolive	Cetylpyridinium chloride 0.075%, glycerin, propylene glycol, sorbitol, poloxamer 407, potassium sorbate, citric acid, sodium saccharin	FD&C[b] Blue No. 1 (CI 42090 – brilliant blue)	4.46
Listerine Tartar Control	Mouth rinse with alcohol and essential oil	Johnson & Johnson	Alcohol 21.6%, thymol 0.064%, eucalyptol 0.092%, methyl salicylate 0.06%, menthol 0.042%, purified water, n-propanol, sorbitol solution, poloxamer 407, benzoic acid, sodium saccharin, zinc chloride, mint flavor, sodium benzoate	FD&C[b] Blue No. 1 (CI 42090 - brilliant blue)	4.10

[a] *pH was determined in triplicate using a table pH meter (MPA 210, MS Tecnopon Instrumentação, Piracicaba, Brazil).*
[b] *US Federal Food, Drug, and Cosmetic Act.*

was covered with a polyester strip and a glass slide, and a 500-g weight was placed on top of it for 10 seconds to remove the air bubbles in the nonpolymerized resin composite. Photoactivation was performed with a third-generation light-emitting diode device (Valo, Ultradent Products, South Jordan, UT, USA) in standard mode, with a 1000 mW/cm^2 irradiance for 20 seconds. Stage I specimens were marked on the side to distinguish the two surfaces of the specimen and act as a guide to set the right direction to make the readings.

Stage I

Color Measurements—The color reading of each specimen was performed initially and 12 hours after immersion in each solution, using a digital spectrophotometer (VITA Easyshade, VITA Zahnfabrik, Bad Säckingen, Baden-Württemberg, Germany) and a white background for standardization. The device was calibrated previously according to the manufacturer's recommendations, and the results were qualified within the CIE L*a*b* system in which the L* coordinate indicates luminosity (black-white axis; 0-100), the a* coordinate means saturation in the red (+) to green (-) axis, and the b* coordinate represents the yellow (+) to blue (-) axis. Color changes were calculated according to the color difference found at the study time points, using the ΔE_{ab} and CIEDE2000 (ΔE_{00}) formulas:

$$\Delta E_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

$$\Delta E_{00} = \sqrt{(\Delta L'/k_L S_L)^2 + (\Delta C'/k_C S_C)^2 + (\Delta H'/k_H S_H)^2 + R_T(\Delta C'/k_C S_C)(\Delta H'/(k_H S_h)}$$

In the ΔE_{ab} formula, L*, a*, and b* represent the coordinates of the CIE L*a*b* system. In the ΔE_{00} formula, ΔL^* represents the variation of the L* coordinate (luminosity, black-white axis); ΔC represents the difference in saturation (chroma); ΔH represents the difference in hue; and R_T is a function that considers the interaction between chroma and hue differences in the blue region of the spectrum. The ΔE_{00} values were calculated according to Sharma and others.[25]

In addition, the shade of each specimen (color according to the VITA scale, ΔSGU) was determined alongside the spectrophotometer reading, following a decreasing order of luminosity, from B1 to C4, based on the VITA scale, according to which each shade was scored from 1 to 16.[26] The score variation was determined and presented as ΔSGU.

Surface Roughness—The Ra of the resin composite specimens was analyzed using a profilometer (Surftest SJ-210, Mitutoyo, Kanagawa, Japan) initially and 12 hours after immersion in each solution. The mean Ra was represented by the arithmetic mean of the peaks and valleys recorded after the profilometer needle moved over a 3.0-mm course on the surface, with a 0.25-mm cutoff. Three readings were performed on each surface, considering that the needle always crossed the geometric center of the specimen but in three different positions. Thus, the mean of the three readings was considered the mean Ra of the specimen.

Exposure to Mouth Rinses for Color Measurement and Ra Analysis—After the initial readings of color and Ra, the specimens were stored in 5 mL[27] of each solution. An *in vitro* 12-hour exposure protocol was suggested to simulate 1 year of daily use of mouth rinse, twice a day, considering a 2-minute exposure.[28,29] The specimens were submitted to constant agitation on a shaker table (SK 0330-Pro, Dragon Laboratory Instruments, Beijing, China) to simulate the mouth rinse movement and determine the homogeneity of the solution.

Stage II

Sorption and Solubility—SR and SL analyses were performed according to ISO 4049:2019. The specimens were stored individually in a desiccator (Vidrolabor, 76335L, Poá, São Paulo, Brazil) containing blue silica and weighed after 24 hours, using an analytical balance (XPR10, Mettler-Toledo, Greifensee, Switzerland). This cycle was repeated until a stable initial mass (*m1*) was obtained, recorded in micrograms (µg). The diameter and thickness of each specimen were obtained using a digital caliper. Accordingly, the volume (V) was obtained in mm^3 using the following formula: , where r is the radius (diameter/2) and h is the average thickness measured.

The specimens were immersed in 2 mL of each solution (see Table 2) for 7 days, renewed daily,[30] and then removed using tweezers, washed abundantly with distilled water, and dried with absorbent paper. Each specimen was left to rest at room temperature for 15 seconds and then reweighed to obtain the mass after immersion (*m2*). The specimens were again stored in the desiccator for 24 hours and weighed following the same stabilization cycle, until a reconditioned mass (*m3*) was obtained.

At this point, the mean values of SR and SL (µg/mm^3) could be obtained using the following formulas:

$$SR = \frac{m2 - m3}{V} \text{ and } SL = \frac{m1 - m3}{V},$$

where V is the mean volume (mm^3), *m1* is the initial mass (µg), *m2* is the mass after 7 days of immersion in each solution (µg), and *m3* is the reconditioned mass. SR was obtained by determining the difference between the mass after immersion and the reconditioned mass over the volume, and SL was obtained by determining the difference between the initial mass and the reconditioned mass over the volume.

Statistical Analyses

The results were submitted to exploratory analysis and assessed for assumptions of normality, homoscedasticity, and data distribution. Color and SL were analyzed by the Kruskal–Wallis and Dunn tests to formulate comparisons among the resin composites and the mouth rinses. Ra was analyzed using generalized linear models for repeated measures. SR was evaluated by a generalized linear model, considering the study factors of resin composite and mouth rinse and the interactions between both. The R Cone Team program (R Foundation for Statistical Computing, Vienna, Austria) was used for all the analyses, adopting a 5% significance level.

RESULTS

Stage I

Color—The color variation of each coordinate and the color change results are presented in Table 3. Regarding ΔL*, there was no significant difference between the resin composites immersed in distilled water (p=0.062) and in the mouth rinse without alcohol (p=0.392). However, conventional nanohybrid (Luna) and bulk-fill nanohybrid composites (Aura) showed higher negative variation of L* (p=0.013 and p=0.047, respectively) toward black compared with conventional nanofilled composite (Z350 XT) after immersion in mouth rinse containing alcohol and essential oil (Listerine). Conventional nanohybrid composite presented a higher ΔL* negative value when immersed in mouth rinse containing essential oil and alcohol vs distilled water (p=0.005).

As for the Δa* values, there was no significant difference among the resin composite groups (p=0.321) immersed in distilled water. All the resin composite groups presented a higher negative variation of a* values (toward green) when immersed in mouth rinse without alcohol vs distilled water (p<0.001). When immersed in mouth rinse without alcohol, bulk-fill nanofilled composite (Filtek One, 3M Oral Care) presented a lower Δa* variation than the conventional nanohybrid and bulk-fill nanohybrid composites (p=0.006). However, when immersed in mouth rinse containing alcohol and essential oil, the conventional nanohybrid composite presented a higher negative variation of Δa* compared with the bulk-fill nanofilled composite (p<0.0001). In addition, the bulk-fill nanofilled composite showed a higher negative variation of Δa* when exposed to mouth rinse with alcohol and essential oil (p=0.008) than distilled water.

Regarding Δb*, conventional nanohybrid composite had significantly lower negative values than conventional nanofilled and bulk-fill nanofilled composites when immersed in distilled water (p<0.01). When immersed in mouth rinse without alcohol, the resin composites showed no significant differences in Δb* (p=0.093). When immersed in mouth rinse with alcohol and essential oil (p<0.001), the conventional nanohybrid and bulk-fill nanofilled composites had more negative

Table 3: *Mean (SD) or Median (Minimum Value; Maximum Value) of Color Parameters According to Resin Composite and Mouth Rinse*[a]

Variable	Resin Composite	Mouth Rinse		
		Distilled Water	Without Alcohol	With Alcohol and Essential Oil
ΔL*	Nanofilled	0.56 (1.11) Aa	-0.02 (0.48) Aa	0.31 (0.47) Aa
	Nanohybrid	0.60 (0.67) Aa	-0.06 (0.69) ABa	-0.61 (1.00) Bb
	Bulk-fill nanofilled	-0.13 (0.53) Aa	-0.13 (0.91) Aa	-0.22 (0.24) Aab
	Bulk-fill nanohybrid	0.28 (0.57) Aa	-0.41 (0.59) Aa	-0.43 (0.67) Ab
Δa*	Nanofilled	0.35 (0.11) Aa	-0.25 (0.28) Bab	0.23 (0.16) Aab
	Nanohybrid	0.44 (0.20) Aa	-0.80 (0.41) Bb	0.41 (0.32) Aa
	Bulk-fill nanofilled	0.34 (0.11) Aa	0.19 (0.63) Ba	-0.16 (0.73) Bb
	Bulk-fill nanohybrid	0.36 (0.30) Aa	-0.64 (0.30) Bb	0.18 (0.20) Aab
Δb*	Nanofilled	-1.63 (1.33) Ab	-1.31 (0.28) Aa	-0.93 (0.31) Ab
	Nanohybrid	0.33 (0.91) Aa	-1.58 (0.50) Ba	-2.10 (1.11) Ba
	Bulk-fill nanofilled	-1.27 (0.54) Ab	-1.91 (0.53) ABa	-2.35 (0.52) Ba
	Bulk-fill nanohybrid	-0.45 (0.34) Aab	-1.67 (0.61) Ba	-1.60 (0.38) Bab
ΔE_{ab}	Nanofilled	1.97 (1.46) Aa	1.42 (0.30) Ab	1.14 (0.23) Ab
	Nanohybrid	1.28 (0.45) Ba	1.90 (0.57) ABab	2.45 (1.11) Aa
	Bulk-fill nanofilled	1.43 (0.53) Ba	2.15 (0.63) Aa	2.45 (0.59) Aa
	Bulk-fill nanohybrid	0.88 (0.34) Ba	1.91 (0.70) Aab	1.79 (0.40) Aab
ΔE_{00}	Nanofilled	1.36 (0.86) Aa	0.99 (0.22) Aa	0.77 (0.16) Ab
	Nanohybrid	0.77 (0.22) Aa	1.08 (0.34) Aa	1.22 (0.52) Aab
	Bulk-fill nanofilled	0.89 (0.23) Ba	1.36 (0.56) Aa	1.50 (0.62) Aa
	Bulk-fill nanohybrid	0.73 (0.32) Ba	1.42 (0.50) Aa	1.14 (0.23) Aa
ΔSGU	Nanofilled	0 (-1; 0) Aa	0 (-1; 0) Aa	0 (-1; 0) Aa
	Nanohybrid	0 (0; 0) Aa	0 (-2; 0) Aa	0 (0; 0) Aa
	Bulk-fill nanofilled	0 (-3; 0) Aa	-1 (-3; 0) ABb	-3 (-3; 0) Bb
	Bulk-fill nanohybrid	0 (0; 0) Aa	0 (0; 0) Aa	0 (0; 0) Aa

[a]Different letters (uppercase letters in rows and lowercase letters in columns) indicate statistical differences (p≤0.05). Resin composites: conventional nanofilled (Filtek Z350XT, 3M Oral Care), conventional nanohybrid (Luna, SDI), bulk-fill nanofilled (Filtek One Bulk- Fill, 3M Oral Care), and bulk-fill nanohybrid (Aura Bulk-Fill, SDI). Rinses: distilled water (control), mouth rinse without alcohol (Colgate Total 12 Clean Mint, Colgate-Palmolive), and with alcohol and essential oil (Listerine Tartar Control, Johnson & Johnson).

Δb* values toward blue than conventional nanofilled composites. Conventional and bulk-fill nanofilled composites ($p<0.001$) presented more negative Δb* values when exposed to mouth rinse without alcohol than distilled water. Lastly, conventional nanohybrid, bulk-fill nanofilled, and bulk-fill nanohybrid composites had more negative values of Δb* in mouth rinse with alcohol and essential oil than distilled water ($p<0.01$).

Considering the color change results, the ΔE_{ab} values were not significantly different among the resin composite groups immersed in distilled water ($p=0.133$) but were significantly higher for bulk-fill nanofilled than conventional nanofilled composites when immersed in mouth rinse without alcohol ($p=0.041$). When exposed to mouth rinse with alcohol and essential oil, the conventional nanohybrid ($p=0.011$) and bulk-fill nanofilled ($p=0.002$) composites presented higher ΔE_{ab} values than the conventional nanofilled composite. Conventional nanohybrid, bulk-fill nanofilled, and bulk-fill nanohybrid composites presented higher ΔE_{ab} values when exposed to mouth rinse with alcohol and essential oil than distilled water ($p<0.0001$). For ΔE_{00}, there were no significant differences among the resin composite groups immersed in distilled water ($p=0.246$) vs mouth rinse without alcohol ($p=0.127$). However, when the resin composites were exposed to mouth rinse containing alcohol and essential oil ($p<0.001$), significantly higher ΔE_{00} values were found in the bulk-

Table 4: *Mean (SD) of Surface Roughness According to Resin Composite, Mouth Rinse, and Time*[a]

Time	Resin Composite	Distilled Water	Mouth Rinse: Without Alcohol	Mouth Rinse: With Alcohol and Essential Oil
Initial	Nanofilled	0.071 (0.026) Ab	0.073 (0.018) Ab	0.073 (0.030) Ab
	Nanohybrid	0.062 (0.013) Ab	0.084 (0.045) Ab	0.066 (0.020) Ab
	Bulk-fill nanofilled	0.085 (0.029) Aa	0.110 (0.030) Aa	0.094 (0.041) Aa
	Bulk-fill nanohybrid	0.116 (0.052) Aa	0.121 (0.050) Aa	0.106 (0.039) Aa
12 hours	Nanofilled	0.074 (0.023) Ab	0.056 (0.011) Ab*	0.067 (0.017) Ab
	Nanohybrid	0.062 (0.011) Ab	0.080 (0.039) Ab*	0.076 (0.027) Ab
	Bulk-fill nanofilled	0.099 (0.031) Aa	0.123 (0.020) Aa*	0.099 (0.034) Aa
	Bulk-fill nanohybrid	0.104 (0.035) Aa	0.081 (0.035) Aa*	0.108 (0.024) Aa

[a] *Means followed by different letters (uppercase letters in rows and lowercase letters in columns within the same time period) indicate statistical differences (p≤0.05). The asterisk (*) indicates a difference from the initial time period for the same resin and mouth rinse conditions (p≤0.05). p(resin)<0.0001; p(mouth rinse)=0.500; p(time)=0.3408; p(resin x mouth rinse)=0.0678; p(resin x time)=0.0659; p(mouth rinse x time)=0.0329; p(resin x mouth rinse x time)=0.513. Resin composites: conventional nanofilled (Filtek Z350XT, 3M Oral Care), conventional nanohybrid (Luna, SDI), bulk-fill nanofilled (Filtek One Bulk- Fill, 3M Oral Care), and bulk-fill nanohybrid (Aura Bulk-Fill, SDI). Rinses: distilled water (control), mouth rinse without alcohol (Colgate Total 12 Clean Mint, Colgate-Palmolive), and with alcohol and essential oil (Listerine Tartar Control, Johnson & Johnson).*

fill composites in comparison with the conventional nanofilled composite (p<0.01). The bulk-fill nanofilled (p=0.005) and nanohybrid (p=0.001) composites presented higher ΔE_{00} values when exposed to both mouth rinses than to distilled water. Considering the color change based on the scores established for the Vita scale, bulk-fill nanofilled composite presented more negative ΔSGU values when exposed to both mouth rinses in comparison with the other resin composite groups tested (p=0.013). Furthermore, the bulk-fill nanofilled composite presented more negative ΔSGU values when immersed in mouth rinse with alcohol and essential oil than in distilled water (p<0.0001).

Surface Roughness—According to the Ra results shown in Table 4, there was no significant difference in the Ra values between the control (distilled water) and both mouth rinse groups (p=0.50). However, the bulk-fill resin composites (Filtek One [3M Oral Care] and Aura [SDI]) presented significantly different and higher Ra values (p<0.0001) than the conventional resin composites (Z350 XT [3M Oral Care] and Luna [SDI]), at both time points analyzed, regardless of the solutions evaluated. Considering the mouth rinse vs time outcomes, a difference was observed between the time points when mouth rinse without alcohol was used (p=0.032). In this case, there was a subtle decrease in the Ra values for the conventional nanofilled, conventional nanohybrid, and bulk-fill nanohybrid composites and a slight increase for the bulk-fill nanofilled composite.

Sorption and Solubility–Table 5 displays the results for SR. A significant difference was observed in the SR values among the composites in the control group (distilled

Table 5: *Mean (SD) of Sorption Values (μg/mm³) According to Composite Resin and Mouth Rinse*[a]

Resin Composite	Distilled Water	Mouth Rinse: Without Alcohol	Mouth Rinse: With Alcohol and Essential Oil
Nanofilled	0.010 (0.004) ABa	0.007 (0.004) Ba	0.012 (0.002) Aa
Nanohybrid	0.004 (0.003) Bb	0.006 (0.002) Ba	0.013 (0.001) Aa
Bulk-fill nanofilled	0.013 (0.008) Aa	0.007 (0.004) Ba	0.011 (0.003) Aa
Bulk-fill nanohybrid	0.006 (0.000) Bb	0.003 (0.005) Ba	0.011 (0.004) Aa

[a] *Means followed by different letters (uppercase letters in rows and lowercase letters in columns within the same time) indicate statistical differences (p≤0.05). Resin composites: conventional nanofilled (Filtek Z350XT, 3M Oral care), conventional nanohybrid (Luna, SDI), bulk-fill nanofilled (Filtek One Bulk- Fill, 3M Oral Care), and bulk-fill nanohybrid (Aura Bulk-Fill, SDI). Rinses: distilled water (control), mouth rinse without alcohol (Colgate Total 12 Clean Mint, Colgate-Palmolive), and with alcohol and essential oil (Listerine Tartar Control, Johnson & Johnson).*

Table 6: *Median (Minimum Value; Maximum Value) of Solubility Values (μg/mm³) According to Composite Resin and Mouth Rinse*[a]

Resin Composite	Distilled Water	Mouth Rinse	
		Without Alcohol	With Alcohol and Essential Oil
Nanofilled	0 (0; 0.006) Aa	0 (-0.006; 0.006) Ab	0.006 (0; 0.007) Aa
Nanohybrid	0 (0; 0.007) Ba	0.007 (0.006; 0.007) Aa	0.007 (0; 0.007) Aa
Bulk-fill nanofilled	0 (0; 0.007) Aa	0 (0; 0.007) Aab	0.006 (0; 0.007) Aa
Bulk-fill nanohybrid	0 (0; 0.007) Aa	0.003 (-0.007; 0.007) Aab	0.006 (0; 0.012) Aa

[a] *Medians followed by different letters (uppercase letters in rows and lowercase letters in columns) indicate statistical differences (p≤0.05). Resin composites: conventional nanofilled (Filtek Z350XT, 3M Oral Care), conventional nanohybrid (Luna, SDI), bulk-fill nanofilled (Filtek One Bulk- Fill, 3M Oral Care), and bulk-fill nanohybrid (Aura Bulk-Fill, SDI). Rinses: distilled water (control), mouth rinse without alcohol (Colgate Total 12 Clean Mint, Colgate-Palmolive), and with alcohol and essential oil (Listerine Tartar Control, Johnson & Johnson).*

water), pointing out that the nanofilled composites (Z350 XT and Filtek One [3M Oral Care]) had higher SR values than the nanohybrid composites (Luna and Aura [SDI]; $p<0.001$). All the resin composite groups presented higher SR when immersed in mouth rinse containing alcohol than mouth rinse without alcohol ($p<0.0001$). Nanohybrid composites also presented higher SR when exposed to mouth rinse containing alcohol in comparison with distilled water ($p<0.0001$).

SL results are presented in Table 6. There was only a significant difference among the resin groups when the mouth rinse without alcohol was used ($p=0.005$). In this case, SL was significantly higher in the conventional nanohybrid than the conventional nanofilled composite ($p=0.004$). Conventional nanohybrid composite presented higher SL in both mouth rinses than in distilled water ($p=0.005$).

DISCUSSION

Even though mechanical control is an effective method for preventing biofilm-related oral diseases, such as caries, gingivitis, and periodontal disease,[31-33] mouth rinses are frequently and widely used by patients.[22] Mouth rinses can be recommended by dentists[34,35] but are often chosen subjectively based on a self-application preference, considering that commercial oral-care products are commonly sold without a professional prescription in markets, pharmacies, and virtual environments worldwide. Thus, the present study was designed to broaden the discussion on the safety of these products, especially by investigating their effects on the relevant properties of commonly used restorative materials.

According to the results, the first null hypothesis was rejected because the mouth rinses tested caused color change and variation in the CIE L*a*b* system coordinates on different scales, even though only slight Ra variation was observed when the mouth rinse without alcohol (Colgate Plax Total 12 Clean Mint, Colgate-Palmolive) was used. Color stability and staining resistance are relevant attributes included among the important clinical properties needed for restorations to succeed in the long term.[17,20] Resin composite pigmentation or staining can occur due to intrinsic discoloration caused by aging[36] or exposure to extrinsic agents, such as the mouth rinses tested. Thus, pigments from the mouth rinses studied or from other sources could have been deposited on the surface of the composites and reacted with their structure by absorption.[18]

The blue colorant evaluated (CI 42090, Johnson & Johnson; Table 2) was found in both mouth rinses, and its incorporation into the resin composite surface or subsurface was confirmed by the variation of b* values toward blue, for all the resin groups tested. Considering the color change values,[37] both mouth rinses caused perceptible color change ($\Delta E_{ab}>1.2$, $\Delta E_{00}>0.8$). Moreover, some of the maximum values of the groups exposed to the mouth rinses (Table 3) exceeded the acceptability thresholds. Overall, the medians did not exceed these limits, meaning that ΔE_{ab} and ΔE_{00} were lower than 2.7 and 1.8, respectively.

The pigmentation dynamic of bulk-fill resin composites has still not been widely investigated, and previous studies have suggested that these composites could present lower[38,39] or higher[40] color stability in comparison with conventional resins exposed to staining. The color results of the present study suggest that the monomeric and translucency modifications of bulk-fill materials could cause alterations in the optical properties, color stability, and susceptibility to the staining of these materials, considering that the bulk-fill composites (Filtek One [3M Oral Care] and Aura [SDI]) presented higher ΔE_{00} when immersed in both mouth rinses vs the control group (distilled water). Furthermore, the ΔSGU values were higher for the bulk-fill nanofilled composite (Filtek One Bulk-Fill, 3M Oral Care) when exposed to the mouth rinse containing essential oil and alcohol (Listerine Tartar Control, Johnson & Johnson), thereby leading to rejection of the third null hypothesis. The pigmentation of the bulk-fill vs conventional composites can be explained by the monomeric alterations of or the prepolymerized particle incorporation into the resin matrix of these materials.[39] However, a previous study[18] suggested that the increase in the color change correlates to an increase in opacity or a decrease in translucency. In this respect, the higher translucency of bulk-fill composites is a mechanism that can be used to increase the depth of cure,[11] but the pigments in a matrix with increased translucency may interfere in the dynamic of light absorption and scattering through the material.

Higher pigmentation was observed with the mouth rinse containing alcohol and essential oil, because it has not only blue colorant and alcohol in its composition but also an acidic pH.[27,41] Therefore, the second null hypothesis was rejected, because the resin composites presented alterations in SR and SL. The change in SR could be seen in the resins exposed to the mouth rinses, especially those immersed in the mouth rinse containing alcohol and essential oil. The change in SL is exemplified by the conventional nanohybrid resin composite (Luna, SDI) that presented higher SL results when exposed to both mouth rinses vs the control. Leal and others[30] also reported a higher occurrence of SR and SL of conventional resin composites when exposed to mouth rinses containing alcohol; their results were replicated for the bulk-fill nanohybrid composite analysis (Aura Bulk-Fill, SDI).

Alcohol is described as an agent that damages the polymeric chains of resin-based composites[42-44] and that can mediate and even intensify the SR and SL of these materials.[45] Alcohol can promote hygroscopic expansion, thereby penetrating inside polymeric chains, acting over cross-links, and expanding and distorting the polymeric network conformity.[46] Moreover, this alteration in the disposition of the polymeric network could cause nonconverted monomers to leach and create porosities in the material.[47] In the present study, the resin composite composition (regarding number and type of filler particles) could have influenced the SR and SL outcomes of the materials tested,[46,48] the degree of conversion, and the type of monomers in the composition.[43] Triethylene glycol dimethacrylate (TEGDMA) and bisphenol A-glycidyl methacrylate (Bis-GMA) are more susceptible monomers that can enhance SR because of their hydroxyl groups and ether bonds, followed by urethane dimethacrylate (UDMA), which contains urethane groups that provide a favorable linkage to alcohol.[30,49] According to Table 1, these monomers can be found in the resin composites tested, especially TEGDMA (Z350 XT, Luna and Aura, SDI), Bis-GMA (Z350 XT and Aura, SDI), and UDMA (Z350 XT, Filtek One Bulk-Fill, [3M Oral Care] Luna and Aura [SDI]).

A higher proportion of inorganic fillers relative to the organic matrix of the composite is associated with higher resistance to SR and SL.[45,50,51] However, in the control group (distilled water), the nanofilled composites (Z350 XT and Filtek One Bulk-Fill, 3M Oral Care) presented higher SR results than the nanohybrid composites (Luna and Aura Bulk-Fill, SDI), thus corroborating previous studies.[52,53] The nanohybrid composite presented higher SL results when exposed to the two mouth rinses tested in comparison with the control, resulting in the possible alteration and impairment of its physical properties.[54,55]

Additionally, the suggested mechanisms of degradation and pigment incorporation elucidate the color change found in this study, thus corroborating the SR and Ra results. Color change is also associated with the surface profile and modification of the light reflection pattern,[56] and the bulk-fill resin composites showed higher RA values regardless of the solution evaluated. Ra is a relevant variable to be evaluated, since it can indirectly reveal the surface degradation of materials, and is associated with color change, susceptibility to staining, and interference in light scattering and reflection.[56] The differences in Ra were found to be material dependent among the resin composites. The change in the monomer composition of bulk-fill resin composites, represented by high-viscosity monomers and methacrylate derivatives, could be associated with the higher Ra value.[57]

The increase in the widespread use of mouth rinses raises important issues about how the dental materials applied in the oral environment might behave when exposed to these products. The findings of the present study complement previous studies,[29,30,58] which have already researched the negative impact of commercial mouth rinses on resin composites properties. The resin composites chosen for this study are used by and validated in the global market. The bulk-fill resin composites came from the same manufacturer as the conventional resins and had the same filler particle size classification. They were chosen to provide a controlled evaluation. As such, it was possible to evaluate whether the effects of mouth rinses on resin composites were composition dependent, in terms of the solutions and the resin materials tested. The present results indicate that the mouth rinses were capable of changing the color of all the resin composite groups tested; however, these alterations were higher in the bulk-fill groups and the resin composite groups exposed to the mouth rinse containing alcohol and essential oil. Further studies should be developed and performed to corroborate and validate the hypotheses proposed and provide better understanding of and safety to the products evaluated.

CONCLUSIONS

The physical properties of resin composites were dependent of manufacturer and resin composition; however, they were mediated by mouth rinses. Higher color change was observed in the bulk-fill resin composites when exposed to mouth rinse containing alcohol and essential oil (Listerine Tartar Control, Johnson & Johnson).

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Conflict of Interest

The authors of this manuscript 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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