Short- and Long-term Effects of Vegan Mouthrinses on Color Stability and Translucency of Single- and Multi-shade Resin Composites

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This study evaluated the effects of vegan mouthrinses on the color stability and translucency of single-shade and multi-shade resin composites. A total of 108 disc specimens from four resin composites (Charisma Smart, Filtek Z250, Vittra APS Unique, Zenchroma) were allocated to control, Grapefruit mouthrinse, and Chios Mastiha mouthrinse groups. Samples were immersed in 12 and 24 hours to simulate 1- and 2-year clinical use. Color (ΔE_{00}) and translucency (ΔRTP_{00}) changes were measured with a spectrophotometer. Data analysis was performed with robust ANOVA ($\alpha = 0.05$). Vegan mouthrinse groups showed greater color change than the control group ($p < 0.001$). Vittra APS Unique showed the highest color change, exceeding clinical thresholds (> 1.8), whereas Charisma Smart was the most stable. In contrast, translucency changes were mainly material-dependent ($p < 0.001$) and were not influenced by solution or time. All ΔRTP_{00} values were within clinically acceptable limits. Vegan mouthrinses had a negative effect on color stability, particularly in single-color resin composite samples; however, their effect on translucency was minimal. Multi-shade resin composites exhibited greater color stability; this indicates that vegan mouthrinses may still be clinically and visually acceptable.

Keywords: color stability, relative translucency, single-shade composites, vegan mouthrinse.

1. INTRODUCTION

The success of esthetic restorative treatments largely depends on the ability of resin composites (RCs) to reproduce the natural color and optical properties of dental tissues. Limitations associated with conventional multi-shade systems have led to the development of single-shade materials with enhanced chromatic adaptability [1]. Despite ongoing advances in material technology, color stability remains one of the major factors influencing the long-term clinical performance of RCs [2]. Discoloration may occur through intrinsic mechanisms, such as matrix degradation and deterioration at the matrix-filler interface, or through extrinsic factors related to the absorption of staining agents [3,4]. Commonly consumed substances, including coffee, tea, and mouthrinses, may accelerate this process and contribute to increased discoloration over time [5].

In recent years, increasing interest in healthy lifestyles and concerns regarding synthetic ingredients have substantially increased the demand for natural and vegan cosmetic products [6]. These products are free from animal-derived components and are primarily formulated using plant-based active ingredients. In addition, they are produced according to a "cruelty-free" approach, which has also gained importance in oral care products [7]. Consequently, interest in plant-based mouthrinses has increased, and these products have emerged as alternatives to conventional formulations. Vegan mouthrinses are generally defined as products that do not contain animal-derived ingredients and are mainly composed of plant-based components. Because of the limitations of mechanical plaque control methods, mouthrinses are commonly used asadjuncts to routine oral hygiene practices [8]. Their widespread use is mainly attributed to their antimicrobial properties, ability to provide oral freshness, and effectiveness in reducing halitosis [9]. The vegan mouthrinses evaluated in the present study did not contain alcohol or organic acids, which have been associated with matrix degradation and discoloration of RCs [5, 9]. In their formulations, xylitol and *Rhus glabra* extract exhibit bacteriostatic and antimicrobial properties [8, 10]. In addition, the mouthrinse containing Chios mastiha includes derivatives of *Pistacia lentiscus*. These compounds may help reduce oral biofilm formation through their antimicrobial, anti-inflammatory, and antioxidant activities and may serve as potential alternatives to conventional chemical antiseptics [11].

Prolonged exposure to mouthrinses may influence the optical behavior of RCs [9]. For long-term esthetic success, restorative materials are expected to mimic the appearance of natural dentition and maintain these optical properties over time. Translucency, which represents the balance between opacity and transparency, can be quantified using the translucency parameter (TP) [12]. In clinical evaluations, the relative translucency parameter (RTP_{00}), which accounts for background effects, together with the CIEDE2000 (ΔE_{00}) formula, is recommended for the assessment of optical properties. These parameters may be influenced by the material composition, thickness, and structural characteristics [13]. A previous study reported that prolonged exposure to different mouthrinses may affect the color stability and translucency of RCs [14]. Although the literature has primarily focused on traditional mouthrinses, evidence regarding the effects of increasingly popular vegan mouthrinses on the optical properties of RCs remains limited. In particular, the optical behavior of

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recently introduced single-shade RCs after exposure to vegan mouthrinses has not been sufficiently investigated. In addition, only a limited number of studies have comparatively evaluated the short- and long-term effects of mouthrinse exposure on the optical properties of RCs. Since mouthrinses are routinely used as part of daily oral hygiene practices, understanding their potential effects on the esthetic longevity of restorative materials is clinically important. Therefore, this study aimed to evaluate the effects of short- and long-term exposure to vegan mouthrinses on the color stability and relative translucency of multi-shade and single-shade RCs. The null hypotheses were as follows: (1) short- and long-term exposure to vegan mouthrinses would not significantly affect the color change of RCs, and (2) such exposure would not significantly affect their relative translucency.

2. EXPERIMENTAL DETAILS

2.1. Materials

In this study, a total of four different RC materials were used: two multi-shade materials [Charisma Smart – A2 (Kulzer, Germany) and Filtek Z250 – A2 (3M, USA)] and two single-shade materials [Vittra APS Unique (FGM, Brazil) and Zenchroma (President Dental, Germany)]. The material compositions and manufacturer details are summarized in Table 1.

Two vegan mouthrinses were evaluated: Grapefruit mouthrinse (GM; Bilka, Bulgaria) and Chios Mastiha mouthrinse (CM; Bilka, Bulgaria). The manufacturer details and chemical compositions of these products are summarized in Table 2.

2.2. Sample size determination

Sample size estimation was performed based on the parameters reported in a previous study [15], using a confidence level of 95 % ($1 - \alpha$), a statistical power of 85 % ($1 - \beta$), and an effect size of $f = 0.25$. According to the analysis, a minimum of eight specimens was required for each subgroup. To compensate for potential specimen loss during the experimental procedures, nine specimens were included in each subgroup.

2.3. Specimen preparation

In this study, 108 disk-shaped specimens (8 mm in diameter and 2 mm in thickness) were prepared from four different RC materials, with 27 specimens allocated to each material group. The specimens were fabricated using Teflon molds, and their surfaces were standardized with Mylar strips and glass slides. Polymerization was performed using an LED light-curing unit (Elipar S10, 3M ESPE, USA) at an intensity of 1200 mW/cm² for 20 s. All procedures were carried out by a single operator to ensure standardization. After polymerization, the specimen surfaces were finished under running water using 1200-grit silicon carbide paper [16].

Table 1. Resin composite materials examined in this study

Resin composites	Manufacturer	Composition	Lot No.
Charisma Smart (A2)	Heraeus Kulzer GmbH, Hanau, Germany	Bis-GMA,TEGDMA,barium aluminum boro fluor silicate glass, silica, titanium dioxide, 0.005 – 10 μm. *(Filler wt.% NA, vol.% 59)*	N010553
Vittra APS Unique	FGM, Joinville, Brazil	UDMA, TEGDMA, average particle size between 0.8 and 0.9 microns, boron aluminum-silicate glass, silicon dioxide, photoinitiator composition (APS). *(Filler wt.% 72–80, vol.% 52 – 60)*	180321
Zenchroma	President Dental, Germany	Bis-GMA, UDMA, tetramethylene dimethacrylate, glass powder, silicon dioxide filler particle sizes ranging from 0.005 – 3.0 μm. *(Filler wt.% 75, vol.% 53)*	9879530
Filtek Z250 (A2)	3M, 3M ESPE Dental Products St.Paul, MN-ABD	Bis-GMA, Bis-EMA, UDMA, TEGDMA, zirconia/silica glass fillers, silane-treated ceramics, aluminum oxide, and titanium oxide, with filler particle sizes ranging from 0.01- 3.5 μm. *(Filler wt.%82, vol.%60)*	9879530

Abbreviations: Bis-EMA, ethoxylated bisphenol A dimethacrylate; Bis-GMA, Bisphenol A-glycidyl methacrylate, TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate

Table 2. List and properties of the mouthrinses examined

Mouthrinses	Manufacturer	Composition	Color
Grapefruit mouthrinse	Bilka, Sofia, Bulgaria	Aqua, Sorbitol*, Xylitol*, Rhus glabra extract*, PEG-40 HCO, Pentylene Glycol, Methyl Diisopropyl Propionamide, Sodium Benzoate, Disodium EDTA, Aroma*, Limonene, Citrus, Geraniol, Linalool.	Orange
Chios mastiha mouthrinse	Bilka, Sofia, Bulgaria	Aqua, Sorbitol*, Xylitol*, Rhus glabra extract*, PEG-40 HCO, Pistacia lentiscus (mastic) gum water*, Pentylene Glycol, Methyl Diisopropyl Propionamide, Sodium Benzoate, Disodium EDTA, Aroma*, Limonene, Eugenol, Linalool.	Orange

Abbreviations: EDTA, ethylenediamine tetra-acetic acid; PEG-40 HCO, polyethylene glycol (40) hydrogenated castor oil.
***** Denotes ingredients of natural origin.

2.4. Grouping of specimens

A total of 108 RC disk specimens were prepared, with 27 specimens assigned to each material group. Each material group was randomly divided into three subgroups (n = 9): control (Group 1), Grapefruit mouthrinse (Group 2), and Chios Mastiha mouthrinse (Group 3).

2.5. Immersion protocol

Each subgroup was immersed in 20 mL of vegan mouthrinse and stored at 37 °C for 12 h. This period simulated approximately one year of clinical use based on twice-daily application [5, 16]. The same specimens were then immersed for an additional 12 h, resulting in a total exposure time of 24 h, which simulated approximately two years of clinical use [5, 17]. Measurement time points were defined as baseline (t_0), after 12 h (t_1), and after 24 h (t_2). Specimens in the control group were kept in distilled water for the same time intervals.

2.6. Color measurements and color differences

Color measurements were obtained at three time points: prior to mouthrinse exposure (t_0), following the 1-year immersion simulation (t_1), and after the 2-year immersion simulation (t_2). Measurements were carried out using a spectrophotometer (VITA Easyshade V; VITA Zahnfabrik, Germany). Each specimen was evaluated on a GC3 card with white (L = 96, a = 0, b = +1) and black (L = 8, a = +1, b = −1) backgrounds to ensure standardization [18]. Three measurements were obtained for each background, and the mean values were calculated. Color differences for the $t_0 - t_1$ and $t_0 - t_2$ intervals were determined using the CIEDE2000 (ΔE_{00}) equation [19]:

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

where $\Delta L'$, $\Delta C'$, and $\Delta H'$ are the differences in lightness, chroma, and hue, respectively; S_L, S_C, and S_H are weighting functions; K_L, K_C, and K_H are correction factors, which were set to 1:1:1 in the present study. The rotation term (R_T) was included to account for interactions, particularly in the blue region [19].

The obtained ΔE_{00} values were interpreted according to the 50 % perceptibility threshold (PT = 0.8) and acceptability threshold (AT = 1.8) [19].

2.7. Relative translucency parameter calculation

The relative translucency parameter (RTP_{00}) was calculated using the CIEDE2000 formula based on measurements obtained on white (L = 96, a = 0, b = +1) and black (L = 8, a = +1, b = −1) backgrounds [13]. Three measurements were obtained for each background, and the mean values were calculated.

$$\mathrm{RTP}_{00} = \left[\left(\frac{L'_B - L'_W}{K_L S_L}\right)^2 + \left(\frac{C'_B - C'_W}{K_C S_C}\right)^2 + \left(\frac{H'_B - H'_W}{K_H S_H}\right)^2 + R_T\left(\frac{C'_B - C'_W}{K_C S_C}\right)\left(\frac{H'_B - H'_W}{K_H S_H}\right)\right]^{\frac{1}{2}}, \quad (2)$$

where the subscript "B" represents the color parameters measured on a black background; "W" refers to those measured on a white background [13].

Relative translucency differences were evaluated according to the 50 % perceptibility threshold (TPT_{00} = 0.62) and the clinical acceptability threshold (TAT_{00} = 2.62) [13].

2.8. Statistical analysis

Data analysis was conducted using Jamovi v2.3.28 (The Jamovi Project, Sydney, Australia). The statistical model included the effects of group, material, time, and their interactions. Since some variables violated the assumptions of normality and homogeneity of variance, a robust ANOVA approach was employed to obtain more reliable estimates and reduce the influence of outliers. In the tables, values reported as "total" were calculated to provide an overall summary of the effects of group, material, and time within the robust ANOVA framework. These values were included to facilitate the interpretation of main effects and potential interactions. Multiple comparisons were performed using the Bonferroni correction. Quantitative data are presented as trimmed mean ± standard error. The main effects of group, material, and time, together with two-way interactions (group × material, group × time, and material × time) and the three-way interaction (group × material × time), were analyzed using a multifactorial model. Descriptive statistics were calculated using a trimmed mean (trimmed value = 0.05) and standard error to minimize the influence of outliers.

3. RESULTS

3.1. Color change results

The effects of group, material, and time on color change and relative translucency were analyzed using robust ANOVA. The results of the main effects and interaction analyses are summarized in Table 3.

Table 3. Robust ANOVA analysis of main and interaction effects of group, material, and time on ΔE_{00} and ΔRTP_{00}

ΔE_{00}	Test statistic	p^x
Group	506.6	<0.001
Material	557.3	<0.001
Time	41.7	0.001
Group × material	412.1	0.001
Group × time	14.5	0.002
Material × time	17.7	0.002
Group × material × time	16.5	0.026
ΔRTP_{00}	Test statistic	p^x
Group	0.234	0.900
Material	142.057	<0.001
Time	0.138	0.712
Group × material	59.720	0.001
Group × time	0.229	0.893
Material × time	2.507	0.486
Group × material × time	3.546	0.758
^{x} robust ANOVA		

The analysis revealed that group, material, and time significantly affected ΔE_{00} values (p < 0.001, p < 0.001, and p = 0.001, respectively). In addition, all two-way interactions (group × material, group × time, and

material × time) as well as the three-way interaction (group × material × time) were found to be significant ($p < 0.05$; Table 3).

Descriptive statistics and multiple comparison results for ΔE_{00} values are summarized in Table 4. The main effect of material revealed the highest ΔE_{00} values for the Vittra APS Unique material and the lowest values for the Charisma Smart material ($p < 0.001$). Regarding the group effect, both mouthrinse groups (Grapefruit mouthrinse and Chios Mastiha mouthrinse) showed higher ΔE_{00} values than the control group ($p < 0.001$). The time effect demonstrated greater color change in the long-term interval ($t_0 - t_2$) compared with the short-term interval ($t_0 - t_1$; $p < 0.05$). However, except for the Vittra APS Unique groups, all ΔE_{00} values in both short- and long-term intervals remained below the clinical acceptability threshold.

Analysis of the three-way interaction (group × material × time) revealed that the lowest short-term ΔE_{00} value was observed in the Charisma Smart × control group ($p < 0.05$). In the long-term interval, the highest ΔE_{00} values were detected in the Vittra APS Unique groups exposed to both mouthrinses (GM and CM; $p < 0.05$; Table 4).

3.2. Relative translucency parameter results

Table 5 summarizes the descriptive statistics and multiple comparison results for ΔRTP_{00} values. Robust ANOVA revealed a significant main effect of material on ΔRTP_{00} values ($p < 0.001$). A significant group × material interaction was also identified ($p = 0.001$; Table 3). The material effect demonstrated the highest ΔRTP_{00} values for the Vittra APS Unique material ($p < 0.001$). Analysis of the two-way interactions revealed the lowest ΔRTP_{00} values in the control group-material combinations ($p < 0.05$). No significant effects were observed for group or time ($p > 0.05$).

The ΔRTP_{00} value in the Charisma Smart × CM group exceeded the perceptibility threshold, whereas all groups remained below the clinical acceptability threshold.

4. DISCUSSION

The findings of this study led to the partial rejection of the null hypotheses. The results demonstrated that vegan mouthrinses significantly affected the color stability (ΔE_{00}) of RCs over time, whereas their effect on relative translucency (ΔRTP_{00}) was limited. Therefore, the first null hypothesis was rejected, while the second was partially rejected. In addition, the findings suggest that color change was influenced by both material type and exposure time, whereas translucency changes were mainly material-dependent and less affected by mouthrinse exposure. Spectrophotometric methods are considered more reliable than visual assessment for the color analysis of RCs [20]. In this study, the CIEDE2000 system, which provides greater sensitivity than the CIE $L^*a^*b^*$ system, was preferred [21]. Replacement of esthetic restorations is frequently associated with discoloration of RCs [4]. Such changes may be related to both the composition of the material and the characteristics of the agents to which it is exposed [17]. Although mouthrinses have generally been reported to cause clinically acceptable levels of discoloration [5, 16], certain components, including chlorhexidine, alcohol, and low pH, have been associated with clinically unacceptable color changes [9, 22].

Table 4. Descriptive statistics and multiple comparison results for ΔE_{00} across groups, materials, and time intervals

Groups	Material	Time interval		Total
		Short-term ($t_0 - t_1$)	Long-term ($t_0 - t_2$)	
Control	Filtek Z250	0.33 ± 0.04^{AJGM}	0.51 ± 0.13^{AJHG}	0.38 ± 0.03^{hi}
	Charisma Smart	0.19 ± 0.04^{LMNJ}	0.28 ± 0.05^{JK}	0.22 ± 0.03^{j}
	Vittra APS Unique	0.37 ± 0.07^{AJ}	0.55 ± 0.07^{ACK}	0.45 ± 0.05^{ah}
	Zenchroma	0.49 ± 0.14^{ACKM}	0.66 ± 0.20^{ACIJ}	0.55 ± 0.11^{aghj}
	Total	0.31 ± 0.02^{C}	0.46 ± 0.05^{BC}	0.37 ± 0.02^{x}
GM	Filtek Z250	0.86 ± 0.07^{CH}	1.05 ± 0.14^{CG}	0.94 ± 0.07^{bfg}
	Charisma Smart	0.36 ± 0.06^{ADFN}	0.61 ± 0.09^{ACK}	0.48 ± 0.06^{ai}
	Vittra APS Unique	3.91 ± 0.38^{E}	5.59 ± 0.45^{E}	4.69 ± 0.32^{e}
	Zenchroma	0.95 ± 0.16^{CDM}	1.43 ± 0.17^{C}	1.18 ± 0.12^{df}
	Total	1.31 ± 0.26^{A}	1.89 ± 0.39^{A}	1.52 ± 0.22^{y}
CM	Filtek Z250	0.43 ± 0.08^{ADGKL}	0.87 ± 0.14^{ACFKL}	0.63 ± 0.10^{abi}
	Charisma Smart	0.51 ± 0.07^{ADGHKL}	0.53 ± 0.07^{ADGHK}	0.52 ± 0.04^{ai}
	Vittra APS Unique	3.47 ± 0.43^{BEI}	4.70 ± 0.47^{BE}	4.07 ± 0.33^{cde}
	Zenchroma	0.88 ± 0.11^{AC}	1.30 ± 0.21^{CK}	1.04 ± 0.09^{b}
	Total	1.10 ± 0.23^{AB}	1.57 ± 0.30^{A}	1.30 ± 0.19^{y}
Total	Filtek Z250	0.53 ± 0.06^{cd}	0.79 ± 0.08^{d}	0.64 ± 0.05^{a}
	Charisma Smart	0.33 ± 0.04^{c}	0.47 ± 0.04^{c}	0.40 ± 0.03^{b}
	Vittra APS Unique	2.53 ± 0.40^{b}	3.59 ± 0.55^{b}	3.02 ± 0.34^{c}
	Zenchroma	0.77 ± 0.08^{ad}	1.11 ± 0.11^{a}	0.93 ± 0.07^{d}
	Total	0.80 ± 0.12^{X}	1.15 ± 0.17^{Y}	

Note: Trimmed mean ± standard error (trimmed value = 0.1); $^{a-d}$ composites sharing the same bold lowercase letter do not differ significantly (main effect: composite); $^{x-y}$ groups sharing the same lowercase letter within a column do not differ significantly (main effect: group); $^{X-Y}$ groups sharing the same uppercase letter within a row do not differ significantly (main effect: time); $^{a-j}$ group×material interactions sharing the same lowercase letter do not differ significantly; $^{A-C}$ group×time interactions sharing the same bold uppercase letter do not differ significantly. $^{a-d}$ material×time interactions sharing the same italic lowercase letter do not differ significantly; $^{A-N}$ group×material×time interactions sharing the same uppercase letter do not differ significantly. The total values represent the means obtained from robust ANOVA analyses and are provided to show the data for the main effects and interaction values; the inferential results are based on robust ANOVA tests.
Abbreviations: GM – grapefruit mouthrinse; CM – chios mastiha mouthrinse.

Table 5. Descriptive statistics and multiple comparison results for ΔRTP_{00} across groups, materials, and time intervals

Groups	Material	Time interval		Total
		Short-term ($t_0 - t_1$)	Long-term ($t_0 - t_2$)	
Control	Filtek Z250	-0.05 ± 0.06	0.03 ± 0.13	-0.04 ± 0.04^{af}
	Charisma Smart	0.04 ± 0.02	-0.14 ± 0.12	-0.01 ± 0.04^{af}
	Vittra APS Unique	0.16 ± 0.27	0.25 ± 0.32	0.17 ± 0.19^{afe}
	Zenchroma	-0.08 ± 0.25	-0.04 ± 0.32	-0.02 ± 0.18^{afde}
	Total	0.01 ± 0.05	0.01 ± 0.08	0.01 ± 0.004
GM	Filtek Z250	-0.02 ± 0.12	0.04 ± 0.15	0.01 ± 0.09^{af}
	Charisma Smart	-0.45 ± 0.16	0.68 ± 0.10	-0.60 ± 0.09^{d}
	Vittra APS Unique	0.50 ± 0.11	0.78 ± 0.21	0.61 ± 0.09^{e}
	Zenchroma	0.16 ± 0.21	0.02 ± 0.18	0.10 ± 0.12^{bf}
	Total	0.05 ± 0.09	0.03 ± 0.11	0.03 ± 0.07
CM	Filtek Z250	0.25 ± 0.14	0.24 ± 0.17	0.22 ± 0.11^{bef}
	Charisma Smart	-0.82 ± 0.20	-0.69 ± 0.15	-0.77 ± 0.10^{d}
	Vittra APS Unique	0.58 ± 0.19	0.64 ± 0.20	0.59 ± 0.12^{be}
	Zenchroma	0.09 ± 0.35	0.20 ± 0.21	0.19 ± 0.16^{bef}
	Total	0.06 ± 0.14	0.10 ± 0.12	0.08 ± 0.09
Total	Filtek Z250	0.04 ± 0.05	0.08 ± 0.07	0.05 ± 0.04^{A}
	Charisma Smart	-0.38 ± 0.11	-0.50 ± 0.08	-0.44 ± 0.06^{B}
	Vittra APS Unique	0.41 ± 0.10	0.55 ± 0.14	0.47 ± 0.07^{C}
	Zenchroma	0.09 ± 0.13	0.11 ± 0.12	0.10 ± 0.08^{A}
	Total	0.04 ± 0.05	0.04 ± 0.06	

Note: Trimmed mean ± standard error (trimmed value = 0.1); $^{A-C}$ composites sharing the same uppercase letter do not differ significantly (main effect: composite). $^{a-f}$ group × material interactions sharing the same lowercase letter do not differ significantly. The total values represent the means obtained from robust ANOVA analyses and are provided to show the data for the main effects and interaction values; the inferential results are based on robust ANOVA tests.
Abbreviations: GM – grapefruit mouthrinse; CM – chios mastiha mouthrinse

A previous study reported the perceptibility threshold (*PT*) and acceptability threshold (*AT*) for ΔE_{00} values as 0.8 and 1.8, respectively [19]. Color changes exceeding these thresholds may become noticeable under clinical conditions. Such alterations may negatively affect the a esthetic appearance and long-term acceptability of restorations. In the present study, the plant-based vegan mouthrinses evaluated did not contain commonly reported staining agents; accordingly, all RCs except Vittra APS Unique exhibited color changes within clinically acceptable limits. Although several groups exceeded the perceptibility threshold in the short- and long-term evaluations, only the Vittra APS Unique groups surpassed the acceptability threshold, suggesting that restoration replacement may not be necessary for the other RCs evaluated in this study. The color stability of RCs mainly depends on the structure of the resin matrix and water absorption [17]. Water absorption may contribute to discoloration by promoting matrix plasticization and facilitating the diffusion of staining agents [5]. Resin systems with a high TEGDMA content have been reported to be more hydrophilic and to exhibit lower color stability [23]. Accordingly, the lower color stability observed in Vittra APS Unique, which has been reported to contain a relatively high proportion of TEGDMA in its resin matrix, is consistent with a previous report [4]. In contrast, higher filler loading reduces the proportion of resin monomer, thereby limiting water absorption and improving color stability [24]. In the present study, the superior color stability observed in Charisma Smart and Filtek Z250, which had the highest filler content among the tested RCs, supports this explanation. Similarly, a previous study evaluating different staining agents reported higher color stability for Filtek Z250 than for Vittra APS Unique [25]. In nanohybrid RCs, microporosities formed as a result of filler particle loss from the surface may facilitate the penetration of staining agents [26]. Submicron hybrid RCs have been reported to demonstrate greater color stability than nanohybrid and microhybrid materials, mainly because of their lower water absorption [27]. Consistent with studies investigating exposure to different solutions [3], the present findings support the higher color stability observed for the submicron hybrid Charisma Smart material.

In the present study, single-shade RCs exhibited greater color change than multi-shade RCs following exposure to vegan mouthrinses. This finding may be related to the structural and optical characteristics of single-shade materials. Previous studies have reported that single-shade systems tend to be more susceptible to staining agents and may exhibit noticeable discoloration despite their chromatic adaptation mechanisms [21, 25]. Although some studies have demonstrated comparable long-term color stability between single-shade and multi-shade restorations [28], the present results are in agreement with studies reporting lower color stability in single-shade RCs [24, 29, 30]. In addition, the higher color stability observed for Zenchroma compared with Vittra APS Unique is consistent with studies reporting similar findings following exposure to different staining agents [20, 30] and thermal aging [2]. The greater color change observed in Vittra APS Unique may be associated with its structural characteristics. Although this material has been reported to exhibit high optical performance because of its advanced polymerization system (APS) [1], the pigments in its composition may increase its susceptibility to extrinsic staining agents [4]. Consistent with this explanation, previous studies have shown lower color stability for this material compared with both single-shade and multi-shade RCs after exposure to various staining solutions [29, 31].

In the present study, higher ΔE_{00} values were observed in the vegan mouthrinse groups than in the control group. Distilled water has also been reported to cause color changes comparable to those induced by mouthrinses under certain conditions [22]. However, the color changes observed in all RCs exposed to distilled water remained below the perceptibility threshold [23], indicating that these changes would not be clinically detectable.

Translucency is an important optical parameter that may influence clinical decisions regarding the placement and replacement of esthetic restorations [20]. In the present study, ΔRTP_{00} values showed significant increases or decreases after immersion in vegan mouthrinses, depending on the material ($p < 0.001$). The Vittra APS Unique group tended to exhibit increased translucency, whereas the Charisma Smart group showed a marked decrease, reflected by negative ΔRTP_{00} values. In contrast, slight increases in ΔRTP_{00} values were observed in the Filtek Z250 and Zenchroma groups, with no statistically significant difference between these materials. However, the relative translucency changes observed in all RCs remained below the clinical acceptability threshold ($TAT_{00} = 2.62$). Therefore, although statistically significant differences were identified, these alterations are unlikely to adversely affect the optical integration and esthetic appearance of the restorations in clinical conditions. Consistent with the present findings, previous studies have reported that exposure to different agents has limited and material-dependent effects on RC translucency [12]. In addition, thermal aging in single-shade RCs has been reported to result in both increases and decreases in translucency; however, these changes generally remain within clinically acceptable limits [32]. Similarly, ΔRTP_{00} values for Filtek Z250, Vittra APS Unique, and Zenchroma have been reported to remain below threshold values after one year of aging [2].

The variation in the direction of translucency change among the tested materials suggests that this property is influenced by the resin matrix structure, filler characteristics, and refractive index compatibility [20, 33]. Structural alterations caused by water absorption and degradation at the filler-matrix interface may increase light scattering, thereby reducing translucency [5, 12]. The higher translucency stability in Filtek Z250, which contains Bis-EMA, may be related to the hydrophobic characteristics of this monomer and its low water absorption [20, 34]. In addition, materials containing Bis-GMA have been reported to exhibit higher translucency than UDMA/TEGDMA systems [33]. Particle size is also considered an important factor affecting translucency, with smaller filler particles enhancing light transmission [35]. In this context, the increased translucency observed in the nanohybrid Vittra APS Unique material may be related to its filler characteristics, the use of more translucent photoinitiators, and its advanced polymerization system [31].

A previous study reported that the optical behavior of single-shade RCs is not uniform [20]. However, another study demonstrated that, after exposure to different beverages, single-shade RCs may exhibit lower ΔRTP values and consequently greater translucency stability than multi-shade RCs [33]. In the present study, no significant difference was observed between the single-shade Zenchroma and the multi-shade Filtek Z250 materials, both of which exhibited high translucency stability following immersion in vegan mouthrinses. The significant group × material interaction further suggests that RCs may respond differently to environmental conditions. Notably, the Charisma Smart material demonstrated a significant reduction in translucency in the mouthrinse groups. Similarly, a previous study reported decreased translucency in a microhybrid RC after mouthrinse exposure compared with distilled water [16].

Overall, these findings highlight the importance of material selection in clinical practice. Although single-shade RCs offer advantages in terms of simplified shade matching and esthetic integration, they may be more susceptible to staining agents over time. In contrast, multi-shade RCs appear to provide more stable long-term color performance. In addition, the herbal mouthrinses evaluated in this study, containing *Pistacia lentiscus* and *Rhus glabra* extracts, demonstrated antimicrobial potential [8, 10, 11] while causing relatively low color alteration. These findings suggest that vegan mouthrinses may represent a promising alternative for clinical use.

This study has several strengths. It is among the few investigations evaluating both color stability (ΔE_{00}) and relative translucency (ΔRTP_{00}) of single-shade and multi-shade RCs under clinically relevant short- and long-term exposure conditions. In addition, the inclusion of vegan mouthrinses represents a novel aspect of the study and expands current knowledge regarding alternative oral hygiene products and their potential effects on restorative materials. The present findings contribute to the limited literature on the effects of vegan mouthrinses on RCs and may provide clinically relevant information for material selection.

Despite its strengths, this study has several limitations that should be considered. The *in vitro* design could not fully reproduce the complex conditions of the oral environment, including salivary flow, enzymatic activity, temperature fluctuations, and mechanical wear. Although the buffering and diluting effects of saliva may reduce alterations in the resin matrix, the acquired pellicle layer formed on restoration surfaces may also affect the interaction between staining agents and the material surface. In addition, only a limited number of RC materials and vegan mouthrinses were evaluated under specific aging conditions. Therefore, the present findings may not be generalized to all restorative materials or oral hygiene products. Furthermore, long-term clinical conditions could not be completely simulated. Future long-term *in vivo* studies are needed to better clarify the effects of mouthrinses on the optical properties and clinical performance of RCs.

5. CONCLUSIONS

Within the limitations of this study, vegan mouthrinses significantly affected the color stability of RCs, while their influence on translucency remained limited and material-dependent. Single-shade RCs exhibited greater color change, while multi-shade RCs demonstrated more stable optical performance. Vittra APS Unique showed color changes exceeding the clinical acceptability threshold in both short- and long-term periods. However, translucency

changes in all materials remained within clinically acceptable limits. These findings highlight the importance of appropriate material selection for esthetic restorations. In terms of optical properties, vegan mouthrinses may provide clinically acceptable outcomes.

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