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Optical Stability of High-translucency Resin-based Composites

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Clinical Relevance

Resin-based composites are able to retain a high-translucency character upon storage.

SUMMARY

This study investigated the stability of the optical properties of high-translucent shades of dental resin-based composites. Four commercial materials (Filtek Z350 XT, Opallis, Amelogen Plus, and IPS Empress Direct) and 14 non-Vita shades were tested. Disc-shaped specimens for each resin-based composite-shade combination (n=6) were evaluated at T_0 (baseline), T_1 (after 30 days of storage in water), and T_2 (after 30 days of storage each in water and a coffee solution). Color measurements were performed according to the $L'C'h'$ color system. Translucency Parameter (*TP*) and CIEDE2000 color difference (ΔE_{00}) were calculated. Data were statistically analyzed at $\alpha = 0.05$. Baseline *TP* values varied from 43 ± 1 to 55 ± 1. Changes in *TP* at T_1 varied from –3.0% (Opallis T-Neutral) to 4.2% (Amelogen Plus Trans Orange), with no major differences from T_0. At T_2, most resin-based composites showed significantly increased opacity, with changes varying between –15.0% (Empress Direct Trans 20) and –2.7% (Z350 XT Blue). However, the *TP* values were $\geq$40 throughout the study. Storage in water caused negligible color differences, with ΔE_{00} values at $T_1 \leq 0.9 \pm 0.6$. At T_2, all materials tested showed significant color difference, and $\Delta E_{00} \geq 3.2 \pm 0.2$. The orange shades from Opallis and Amelogen Plus showed lower color variation than did the other shades. The most significant optical changes upon storage were detected in the hue and particularly the chroma color coordinate. In conclusion, the high-translucent resin-based composites showed large variability in the stability of their optical properties among the tested brands and different shades of the same material. Regardless of the storage condition, the tested resin-based composites retained their high-translucency character over time.

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INTRODUCTION

The color stability of dental esthetic restoratives is of the utmost importance for their long-term performance. Resin-based composites are known for not having the same color and optical stability as dental ceramics during clinical service.[1,2] This has been explained by the intrinsic characteristics of dental polymers, which are more hydrophilic because of the presence of organic components that include ester linkages. After the restoration is complete, the humidity of the oral environment causes water from the saliva to penetrate and soak the restorative. With time, the water may impose hygroscopic and hydrolytic effects to different extents in the resin-based composites depending on their formulation, including their organic matrix components, inorganic filler loading, and particle size.[3-6]

It has been previously reported[7] that intrinsic discoloration of dental resin-based composites may occur as a result of the oxidation of unreacted monomers and polymerization promoters that are entrapped in the polymer network, which modifies the optical properties over time. Therefore, consumption of the polymerization promoters is crucial, although a previous study[8] found no correlation between the amount of remaining C=C and the color instability in resin-based composites. Water diffusion inward and outward may be accompanied by ions and small pigments, which can deposit on the polymer network and cause extrinsic staining. In addition, the interface between the filler particles and polymer matrix is susceptible to hydrolysis, which can contribute to optical instability through modification of the light-scattering characteristics of the surface particles.[9] The dietary and oral hygiene habits of the patient significantly affect the presence of pigments in the mouth, the mechanical and chemical degradation of the restorative,[10] and the overall color stability of the resin-based composites.

As a result of increasing esthetic demand and technical improvements in the fabrication of resin-based composite restorations in anterior teeth, high-translucency composite shades are becoming increasingly popular. Translucency refers to the passage of light through a material with associated light dispersion and is different from transparency. High-translucent resin-based composites are usually not available in conventional Vita shades. These resin-based composites are used to mimic the natural translucency and optical effects of dental tissues in the fabrication of anterior opalescent walls and lingual tooth faces. They can also be used in between layers of more chromatic resin-based composite shades to yield optical effects such as amber or blue hues in transmitted light. However, little is known about the optical properties of these materials. A previous study[3] reported that bisphenol A diglycidyl ether dimethacryalate (Bis-GMA)–based composites are more translucent than urethane dimethacrylate (UDMA)– and triethylene glycol dimethacrylate (TEGDMA)–based materials. Another report[11] observed that bleached resin-based composite shades became slightly more opaque after ageing. However, the literature lacks studies on the stability of the optical properties of high-translucency resin-based composites. For instance, it is unknown whether they retain their translucent character upon ageing. A previous study[12] showed that the less chromatic resin-based composite shades tend to have lower color stability than do the more chromatic shades. It is possible that the highly translucent character may compromise the optical stability, since pigments and oxidized unreacted species may become more apparent in the bulk of the restoration.

The aim of this study was to investigate the stability of the optical properties of high-translucent shades of dental resin-based composites. Four commercial materials and 14 high-translucent non-Vita shades were evaluated. The research hypotheses were the following: 1) ageing negatively affects the color stability; and 2) the resin-based composites would retain their highly translucent character over time.

METHODS AND MATERIALS

Study Design and Materials Tested

This *in vitro* study evaluated the influence of storage conditions (30 days in water or 30 days each in water and a coffee solution) on the optical properties of four commercially available high-translucency resin-based composites. In total, 14 groups were tested, as multiple high-translucent shades were available for each resin-based composite. Table 1 lists the composition and characteristics of all the materials tested. The sample size was calculated based on the translucency data reported in a previous study,[13] considering a comparative design of four independent groups, an average minimum detectable difference in the means of 1.05, an expected standard deviation in the residuals of 0.4, a power of test of 0.8, and $\alpha = 0.05$. An extra specimen was added to the calculation, bringing the final sample size to six per group. The color measurements for each specimen were carried out 24 hours after photoactivation (baseline, control for each group) and repeated after the two storage periods. The response variables were color difference (ΔE_{00}), calculated by the CIEDE2000 method,[11,12] and translucency parameter (*TP*).[14]

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Table 1: *Composition of the Commercially Available Resin-based Composites*[a]

	Shade	Resin Phase	Inorganic Phase, wt% (vol%)	Particle Size Range, µm (Mean)	Photoinitiator System
Filtek Z350 XT (3M ESPE, St Paul, MN, USA)	Blue Clear Gray Amber	UDMA, Bis-EMA, Bis-GMA, PEGDMA, TEGDMA	72.5 (55.6)	0.6-1.4 (n.a.)	CQ/amine
Amelogen Plus (Ultradent, South Jordan, UT, USA)	Trans Gray Trans White Trans Orange	Bis-GMA, TEGDMA	76 (61)	n.a. (0.7)	CQ/amine
Opallis (FGM, Joinville, SC, Brazil)	T-Blue T-Neutral T-Yellow T-Orange	Bis-GMA, Bis-EMA, TEGDMA, UDMA	78.5-79.8 (57-58)	0.04-2.0 (0.5)	CQ/amine
IPS Empress Direct (Ivoclar Vivadent, Schaan, Liechtenstein)	Trans 20 Trans Opal Trans 30	UDMA, TCDDMA, Bis-GMA	49-57 (34-36)	0.04-3 (0.55)	CQ/amine + Lucirin TPO

Abbreviations: Bis-EMA, bisphenol A ethoxylated dimethacrylate; Bis-GMA, bisphenol A glycidyl dimethacrylate; PEGDMA, polyethylene glycol dimethacrylate; TCDDMA, tricyclodecane dimethanol dimethacrylate; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate.
[a] Information contained in material safety data sheets. n.a. indicates that information is not available.

Preparation of Specimens

Six disc-shaped specimens were prepared for each resin-based composite using a cylindrical metal mold (6-mm inner diameter, 1.5-mm thickness). After the resin-based composite was inserted into the mold, the top surface was covered with a Mylar strip and flattened by pressing down with a glass slab using light pressure. The specimens were photoactivated according to the recommendations of the manufacturers from the top surface using a large spectrum LED curing unit (Bluephase G2; Ivoclar Vivadent, Schaan, Liechtenstein) operated in the high mode with 1200 mW/cm^2 irradiance, which was monitored throughout the study. All of the specimens were polished on both surfaces using a mechanical polisher (Buehler, Lake Bluff, IL, USA) with 2000- and 3000-grit silica carbide abrasive papers under continuous water cooling.[15] The thickness of each specimen was measured with a digital caliper with 0.01-µm resolution (Digimatic Caliper; Mitutoyo, Tokyo, Japan).

Optical Data

Color measurements of the specimens were performed according to the $L'C'h'$ color system, in the SCI mode,[16] over a zero-calibrating box using a spectrophotometer equipped with an integrating sphere and diffuse illumination from xenon lamps (SP60; X-rite, Grand Rapids, MI, USA). The measuring aperture was 6 mm in diameter. The illumination and viewing configurations complied with the CIE 10° observer geometry and D65 illuminant.[17] The analyses were performed placing the specimens against three different backgrounds: gray (L^*=52.2, a^*=0.4, b^*=–4.6), white (L^*=89.6, a^*=0, b^*=1.3), and black (L^*=14.6, a^*=0.9, b^*=–3.2). The color measurements were performed in triplicate at the center of the top surface of each specimen and the average was used. A water-based glycerin gel was interposed between the specimen and backgrounds to maintain the optical continuity between the translucent material and the opaque backings. The L^*, a^*, and b^* values were automatically provided by the spectrophotometer. In the $L^*a^*b^*$ color system, L^* represents the lightness, where 100 is white and 0 is black, and a^* and b^* represent the red-green and yellow-blue chromaticity coordinates, respectively. In the $L'C'h'$ color system, L' represents the lightness, C' the chroma, and h' the hue. They were calculated using the following formula[18]:

$$L' = L^*, C' = \sqrt{a'^2 + b'^2}, \text{ and } h' = tan^{-1}(b'/a')$$

Considering

$$a' = (1+G)a^*,\ b' = b^*, \text{ and } G = \left(1 - \sqrt{\frac{C^*}{C^{*7} + 25^7}}\right)$$

Color Stability

The color measurements for all materials were performed in three different periods. The baseline values (T_0 = control) were taken 24 hours after the polymerization of the specimens, which were dry-stored in the dark. The specimens were then immersed in distilled water at 37°C for 30 days and

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the color measurements were repeated (T_1). The final measurements were performed after the immersion of the specimens in a coffee solution at 37°C for 30 days (T_2). The coffee solution was prepared according to the method described in a previous report.[19] The immersion medium was not renewed during storage. Color stability was estimated by the CIEDE2000 color difference (ΔE_{00}), using the color coordinates measured over the gray background, calculated according to the following formula[17,20]:

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

by considering

$$\Delta L' = L'_1 - L'_2,\ \Delta C' = C'_1 - C'_2,$$

$$\Delta H' = \sqrt[2]{C'_1 C'_2 sin\left(\frac{\Delta h'}{2}\right)},\ \text{and } \Delta h' = h'_1 - h'_2$$

where $\Delta L'$, $\Delta C'$, and $\Delta H'$ are the mathematical differences in lightness, chroma, and hue, respectively, between the two measurement periods (ie, water storage vs baseline/T_1-T_0; and water + coffee storage vs baseline/T_2-T_0). The rotation term R_T is a function that accounts for the interaction between chroma and hue differences in the blue region, improving the color difference equation performance. For dental color space, the R_T value is close to zero.[21] $K_L S_L$, $K_C S_C$, and $K_H S_C$ are empirical terms used for weighting the metric differences to the CIEDE2000 differences for each coordinate. Parametric factors were set to $K_L = 2$, $K_H = 1$, and $K_C = 1$ according to the better performance of the ΔE_{00} equation.[22,23] During ΔE_{00} calculation, the discontinuities due to mean hue computation and hue difference were taken into account, as pointed out previously.[20]

Translucency

Translucency of each specimen was calculated using the *TP* formula, thus[14]:

$$TP = [(L*_w - L*_b)^2 + (a*_w - a*_b)^2 + (b*_w - b*_b)^2]^{1/2}$$

where w refers to the CIELAB values for each specimen measured over the white background and b over the black background. The *TP* was calculated for each storage period.

Statistical Analysis

The analyses were conducted using Sigma Plot v13.0 software (Systat Software, San Jose, CA, USA). Data for individual color coordinates L', C', and h', *TP,* and ΔE_{00} were analyzed using two-way repeated-measures analysis of variance (shade vs ageing condition), with one-factor repetition. Comparisons between the different resin-based composites were not performed. All pairwise multiple comparison procedures were performed using the Student-Newman-Keuls post hoc method. The analyses were performed at $\alpha = 0.05$.

RESULTS

Translucency

Results for *TP* are shown in Table 2. For all resin-based composites tested, the factors of shade ($p<0.01$) and ageing condition ($p<0.001$) were significant, whereas the interaction between the two factors was not significant ($p\geq0.08$), except for Amelogen Plus ($p=0.031$). Changes in *TP* after 30 days of water storage varied from –3.0% (Opallis T-Neutral) to 4.2% (Amelogen Plus Trans Orange). In general, the resin-based composites showed no significant differences in translucency between T_0 and T_1, except for Amelogen Plus Trans Orange, which became significantly more translucent. After storage in coffee, changes in *TP* were always negative (increased opacity), varying between –15.0% (Empress Direct Trans 20) and –2.7% (Z350 XT Blue). A significant decrease in *TP* was observed at T_2 for all resin-based composites except the shades Blue and Amber (Z350 XT) and Trans Gray (Amelogen Plus). The material with the least stable *TP* upon storage was Amelogen Plus Trans Orange, which showed significant differences in *TP* in all storage periods. When the different shades were compared within each resin-based composite, the *TP* was significantly lower for the Blue shade from Z350 XT, the T-Neutral shade from Opallis, and the Trans 20 shade from Empress Direct. The resin-based composite Amelogen Plus showed negligible differences in *TP* among the different shades.

Color Stability

Results for ΔE_{00} are shown in Table 3. For all resin-based composites except Z350 XT, the factors shade ($p\leq0.014$) and ageing condition ($p<0.001$) were significant, as was the interaction between the two factors ($p<0.001$). For Z350 XT, the ageing condition was the only significant factor ($p<0.001$). After storage in water (T_1), all resin-based composites

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Table 2: *Translucency Parameter (TP) Means ± Standard Deviations and Percentage Alteration in TP (ΔTP) Upon Ageing (n=6)*[a]

	Shade	Ageing Condition			ΔTP	
		T_0	T_1	T_2	T_1 vs T_0, %	T_2 vs T_0, %
Filtek Z350 XT (3M ESPE)	Blue	47.4 ± 0.8 A,b	48.0 ± 0.9 A,b	46.1 ± 1.3 A,b	1.3	−2.7
	Clear	52.6 ± 0.5 A,a	54.4 ± 2.2 A,a	49.8 ± 1.9 B,a	3.4	−5.3
	Gray	51.6 ± 1.1 A,a	52.0 ± 1.3 A,a	49.4 ± 1.8 B,a	0.8	−4.3
	Amber	52.5 ± 0.7 A,a	52.6 ± 2.0 A,a	48.7 ± 2.0 A,a	0.2	−7.2
Opallis (FGM)	T-Blue	50.0 ± 0.5 A,b	49.7 ± 1.0 A,b	47.7 ± 2.1 B,b	−0.6	−4.6
	T-Neutral	46.5 ± 3.2 A,c	45.1 ± 0.9 A,d	41.3 ± 1.2 B,c	−3.0	−11.2
	T-Yellow	54.6 ± 1.1 A,a	54.4 ± 0.8 A,a	50.4 ± 0.9 B,a	−0.4	−7.7
	T-Orange	47.5 ± 1.9 A,c	47.4 ± 0.5 A,c	43.3 ± 2.1 B,c	−0.2	−8.8
Amelogen Plus (Ultradent)	Trans Gray	44.8 ± 1.4 A,a	44.7 ± 1.4 A,b	41.9 ± 1.5 A,a	−0.2	−6.5
	Trans White	46.1 ± 1.5 A,a	46.9 ± 1.2 A,a	43.4 ± 1.5 B,a	1.7	−5.9
	Trans Orange	44.9 ± 1.1 B,a	46.8 ± 1.1 A,a	39.9 ± 1.3 C,a	4.2	−11.1
IPS Empress Direct (Ivoclar Vivadent)	Trans 20	43.4 ± 1.0 A,c	45.2 ± 3.0 A,b	36.9 ± 1.3 B,b	4.1	−15.0
	Trans Opal	49.9 ± 1.2 A,b	50.3 ± 1.0 A,a	44.4 ± 0.9 B,a	0.8	−11.0
	Trans 30	52.7 ± 1.6 A,a	51.2 ± 1.3 A,a	45.6 ± 2.4 B,a	−2.8	−13.5

[a] *T_0, baseline; T_1, 30 days of water storage; T_2, 30 days of water storage + 30 days of coffee storage. For each resin-based composite, distinct capital letters in the same line indicate significant differences between the ageing conditions, and distinct lowercase letters in the same column indicate significant differences between the shades ($p<0.05$). Comparisons between the different resin-based composites were not performed.*

showed negligible color differences, with ΔE_{00} values below 1.25, which has been reported[21] to correspond to 50% of visual perceptibility under clinical conditions and is herein used as a reference for the visually detectable color changes. After storage in coffee solution (T_2), all materials tested showed significant color difference compared with water storage. There were significant differences between the different shades for some resin-based composites, but all ΔE_{00} values were above 1.25. The orange shades from both Opallis and Amelogen Plus showed lower color variation than did the other shades.

L', C', and h' Color Coordinates

Results for lightness (L'), chroma (C'), and hue (h') are presented in Figure 1. The L' coordinate was not

Table 3: *CIEDE2000 Color Difference (ΔE_{00}) Means ± Standard Deviations (n=6)*[a]

	Shade	Ageing Condition	
		T_1 vs T_0	T_2 vs T_0
Filtek Z350 XT (3M ESPE)	Blue	0.6 ± 0.3 B,a	4.0 ± 0.2 A,b
	Clear	0.6 ± 0.1 B,a	4.9 ± 0.6 A,a
	Gray	0.5 ± 0.1 B,a	4.4 ± 0.4 A,ab
	Amber	0.5 ± 0.2 B,a	4.3 ± 0.3 A,ab
Opallis (FGM)	T-Blue	0.7 ± 0.2 B,b	4.8 ± 0.7 A,a
	T-Neutral	0.6 ± 0.2 B,b	5.5 ± 0.7 A,a
	T-Yellow	0.9 ± 0.2 B,a	5.0 ± 0.5 A,a
	T-Orange	0.8 ± 0.2 B,ab	3.5 ± 0.6 A,b
Amelogen Plus (Ultradent)	Trans Gray	0.6 ± 0.2 B,a	5.6 ± 0.6 A,a
	Trans White	0.7 ± 0.4 B,a	5.6 ± 0.4 A,a
	Trans Orange	0.9 ± 0.6 B,a	3.2 ± 0.2 A,b
IPS Empress Direct (Ivoclar Vivadent)	Trans 20	0.5 ± 0.3 B,a	8.8 ± 0.3 A,b
	Trans Opal	0.5 ± 0.2 B,a	10.0 ± 0.6 A,a
	Trans 30	0.5 ± 0.2 B,a	8.6 ± 0.6 A,c

[a] *T_0, baseline; T_1, 30 days of water storage; T_2, 30 days of water storage + 30 days of coffee storage. For each material, distinct capital letters in the same line indicate significant difference between the ageing conditions, and distinct lowercase letters in the same column indicate significant difference between the shades ($p<0.05$). Comparisons between the different resin-based composites were not performed.*

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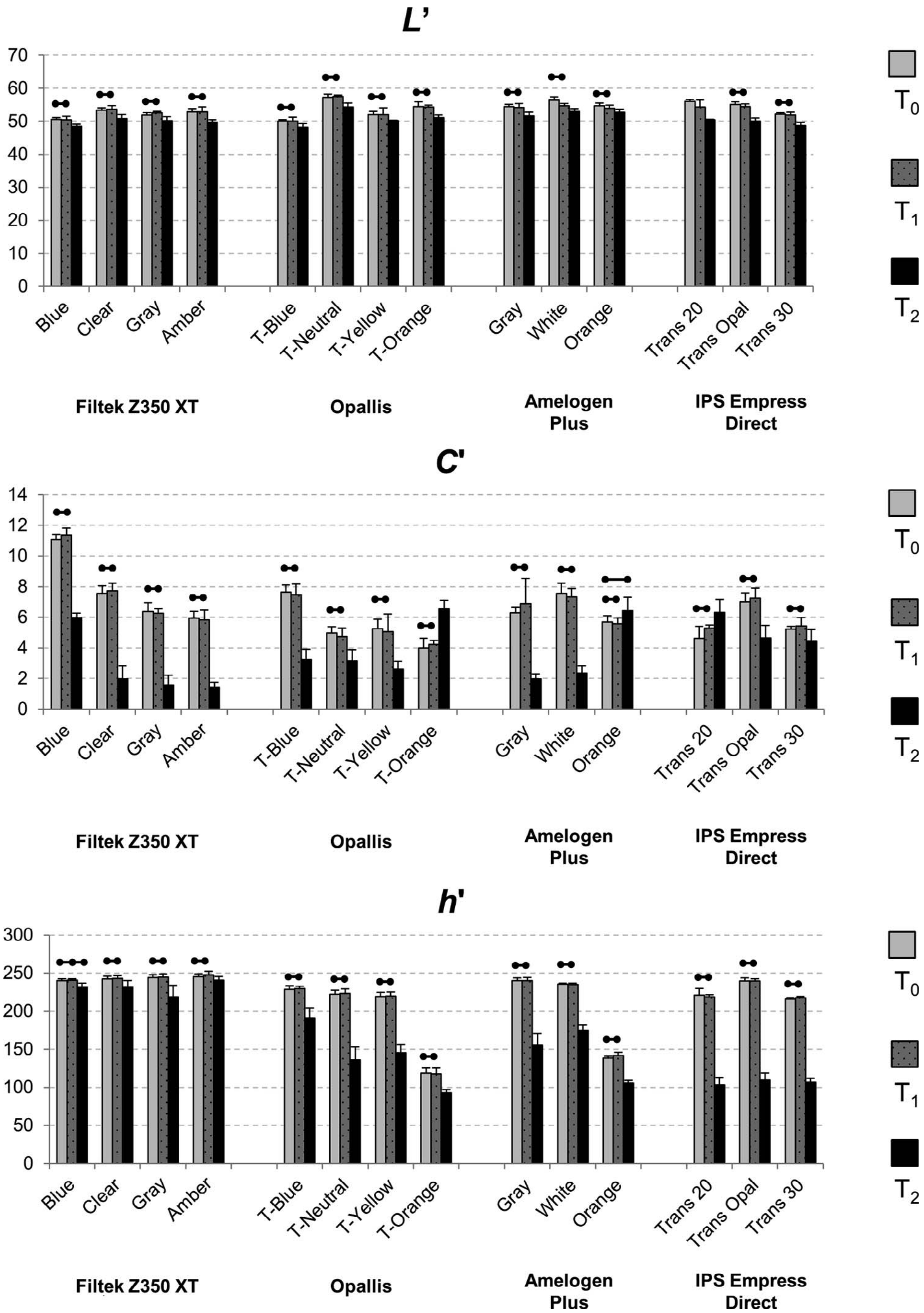

Figure 1. *Results for lightness (L′), chroma (C′), and hue (h′) of all resin-based composites and shades tested. The bars indicate means ± standard deviations (n=6). The connected dots above bars for each shade indicate no significant differences between the ageing periods: T_0, baseline; T_1, 30 days of water storage; T_2, 30 days of water storage + 30 days of coffee storage.*

affected by water storage for most resin-based composites and shades tested, except Trans 20 (Empress Direct), which had slightly but significantly lower L' at T_1. The lightness was significantly lower for all materials after storage in coffee (T_2). Significant changes upon storage were detected in the C' coordinate, particularly at T_2. A significant reduction in C' was observed for all shades from Z350 XT and for most shades from Opallis and Amelogen Plus, except the orange shades, which showed significantly higher C' after storage in coffee. For Empress Direct, the changes in C' at T_2 tended to be less pronounced compared with the changes associated with the other resin-based composites. For the h' coordinate, the changes upon storage were negligible for Z350 XT, whereas the other resin-based composites showed significant reductions in h' at T_2.

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DISCUSSION

This study is the first to investigate the color stability of high-translucency resin-based composite shades. To the best of our knowledge, no previous reports on the optical properties of high-translucent resin-based composites can be found in the literature. The baseline average *TP* values varied from 43 to 55. These values are two to seven times higher than those reported in the literature for conventional, chromatic resin-based composites, which have *TP* values ranging between 8 and 21 for specimens with 1.0 to 1.5 mm in thickness.[10,16,18] This suggests that the materials tested here have high translucency and are suitable for use in anterior restorations when the clinician desires optical effects.

The resin-based composites tested herein are commercially available in shades that are not compatible with the conventional Vita shade guide, and the same manufacturer usually offers different shades. In this study, differences in translucency were observed between resin-based composite brands and within shades of the same resin-based composite. These findings can be explained by the presence of pigments and other components added to tune the optical effects of these resin-based composites, which are available in orange, yellow, blue, and other shades. The translucency of dental resin-based composites is determined by macroscopic phenomena such as monomer characteristics, particle composition, and filler content, as well as by relatively minor pigment additions and potentially by all other chemical components.[13,14] Different materials and shades are likely to exhibit minor changes in composition to achieve the optical effects intended by the manufacturer. These minor changes may lead to significant changes in translucency. However, even after storage in coffee solution for 30 days, yielding significant changes in the individual color coordinates and overall stability, the restoratives retained their highly translucent character. Thus, the tested hypotheses could not be rejected.

The effects of water storage on color stability are likely to be related to the leaching or oxidation of the unreacted polymerization promoters and monomers, since longer ageing times are needed to observe polymer degradation effects.[22] In general, water ageing caused negligible changes in *TP*, lightness, chroma, and hue for most resin-based composites, but there were few exceptions. Resin-based composites from different manufacturers vary in the concentration and structure of their photoinitiators and reducing amines. These differences are also present between different non-Vita shades from the same resin-based composite brand. Variations in the formulation of the resin phase and polymer swelling characteristics may have implications for color stability during water storage. The refractive index of the polymer is different from that of water, altering the light transmission after water accesses the polymer structure and leading to changes in color perception.[23] From a clinical standpoint, these results suggest that the actual optical characteristics of a resin-based composite restoration can only be determined after a certain amount of intraoral ageing. In the ageing process, the restorative is soaked by water and unreacted polymerization promoters or monomers dissolve or are removed.

The color and translucency alterations caused by ageing in coffee were more pronounced than those effects caused by water. The effects of coffee are related to the adsorption pigments and their deposition in the polymer structure. Changes at T_2 are a summation of both water and coffee storage, since the specimens were exposed to the coffee solution after ageing in water for 30 days. Storage in coffee caused a slight decrease in L' and an overall reduction in *TP*. It has been reported[24] that the translucency of resin-based composites is mainly influenced by changes in lightness. Because it is a dark solution, coffee possesses a large amount of pigments that may deposit into the bulk of the restorative, absorb more light, and increase light diffusion, resulting in increased opacity.[25] However, the resin-based composites were still able to retain their high-translucency character over time. The most appreciable changes from coffee exposure were related to hue and particularly chroma. A previous study[12] reported that exposure to coffee may cause dental resin-based composites to redden. However, the discoloration by coffee is often attributed to its yellow pigments.[26] The polarity compatibility between the polymer and coffee colorants likely facilitates their incorporation into the restorative. These findings are in agreement with those of previous studies[24,27] that compared the behavior of resin-based composites after immersion in different beverages and observed that beverages with yellowish pigments were more likely to cause significant color alterations.

The various resin-based composites and shades tested here have differences in inorganic filler loadings. With higher filler content, less resin phase is present, and it would be expected that the resin-based composites with lower particle contents exhibit higher optical instability. The resin-based composite Empress Direct presented lower translu-

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cency stability than did the other restoratives and the highest ΔE_{00} values upon storage. Empress Direct has the lowest filler content among all restoratives tested. In addition, it presents a different photoinitiator system. This higher optical instability could be a result of increased water sorption, leaching and oxidation of unreacted species, and the higher absorption of pigments.[5] A recent study investigating the degradation of the optical and surface properties of resin-based composites indicated that other factors may also influence their ageing resistance, such as the surface area of the fillers and the quantity and type of the coupling agent used to bond the particles with the resin phase.[6] As mentioned previously, the color and translucency stability of the resin-based composite are likely affected by all the components of the material, including the organic matrix formulation, type and quantity of coupling agent, as well as the type and size of the reinforcing inorganic particles.[8,26] Polymeric characteristics may also interfere with the performance of resin-based composites upon ageing, with the degree of C=C conversion and crosslink density of the network having the most significant influences. Finally, the orange shades from two resin-based composites tested herein showed lower color difference than the other shades and an increase in chroma upon storage. This finding could be explained by the similar color between the coffee pigments and the orange shades, reducing the overall staining effects.

In the oral environment, dental resin-based composite restorations are subjected to many chemical and physical challenges that together may significantly influence the stability of their optical properties during clinical service. It has been reported that the surface free energy of resin-based composites is significantly increased by water storage and that saliva coating may influence the physicochemical surface characteristics of resin-based composites, including their surface charge and hydrophobicity.[13] Therefore, surface characteristics may have significant implications in terms of the retention of pigments and their subsequent adsorption by the polymer. The translucency is mainly influenced by the scattering of light at multiple scattering centers within the material, such as the opacifiers or pigments,[28] and may change as a function of the wavelength of the incident light.[14] In the case of high-translucent resin-based composites, the present study indicates that they were able to maintain their high-translucency character upon ageing, but large variations in the optical properties and stability were observed among the different materials. A systematic review highlighted that even different types of finishing and polishing systems may affect the maintenance of surface smoothness and gloss of the chromatic resin-based composites over time.[29] These findings suggest that close follow up of the patients who received resin-based composite restorations would be beneficial for the study of the stability of the optical properties of the treatments.

CONCLUSIONS

Within the scope of this *in vitro* study, the following conclusions can be drawn:

- High-translucent resin-based composites showed large variability in the stability of their optical properties among the resin-based composite brands and different shades of the same material;
- Ageing in water had minor effects on color and translucency stability, whereas ageing in coffee had a more significant impact on the optical properties;
- The chroma and hue color coordinates experienced greater effects than did lightness on color alteration; and
- Regardless of the storage condition, the tested resin-based composites retained their high-translucency characteristics over time.

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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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