

CLINICAL RESEARCH

Color stability of ceramic laminate veneers cemented with light-polymerizing and dual-polymerizing luting agent: A split-mouth randomized clinical trial



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Dental ceramics are widely used for esthetic restorative treatments owing to their desirable characteristics: color stability, translucency, tooth-like optical properties, mechanical resistance, durability, and compatibility with periodontal tissue.<sup>1-4</sup> A popular approach for esthetic treatments is the use of laminate veneers, which are indicated to increase tooth size, reduce diastemas, and to correct form and discoloration.<sup>1,5</sup> With the evolution of adhesive systems, resin cements and ceramic materials, it is now possible to attach 0.1- to 0.7-mm-thick ceramic laminate veneers with minimal or no tooth preparation.<sup>1,3,6-8</sup>

The color stability of the luting agents influences the esthetic result of ceramic restorations, which is a determinant of long-term success,<sup>3,6,9</sup> especially in highly translucent restorations.<sup>10,11</sup> Any alteration of the cement color that results in a

mismatch with the adjacent teeth is a reason for restoration replacement<sup>6,12</sup> and may be considered a treatment failure.<sup>12</sup>

ABSTRACT

**Statement of problem.** The color stability of luting agents influences the esthetics of ceramic laminate veneers. Clinical studies that have evaluated the color changes of veneers cemented to enamel with light- and dual-polymerizing resin cement are lacking.

**Purpose.** The purpose of this split-mouth randomized clinical trial was to evaluate the color change and marginal discoloration of dual- and light-polymerizing cement used for cementation of ceramic laminate veneers.

**Material and methods.** In 10 participants, 0.3-mm-thick ceramic laminate veneers were cemented on the buccal surface of the second premolars without tooth preparation. A randomized application of light-polymerized cement was used on one side and a dual-polymerized cement on the contralateral side. The operator and participants were blinded to the activation mode. Color was evaluated by a blinded evaluator with a spectrophotometer at 24 hours and at 2, 6, 12, and 24 months after cementation. The CIE Lab ( $\Delta E^*_{ab}$ ) and CIEDE2000 ( $\Delta E^*_{00}$ ) formulas were used to quantify color alteration, and  $\Delta a^*$ ,  $\Delta b^*$ , and  $\Delta L^*$  were calculated between the first and subsequent measurements. US Public Health Service guidelines were used to evaluate the marginal discoloration.

**Results.** Wilcoxon tests did not show a statistical difference in  $\Delta E^*_{ab}$  and  $\Delta E^*_{00}$  between the groups ( $P>.05$ ). At 24 months, the median  $\Delta E^*_{ab}$  was 2.31 (interquartile ranges [IQR]: 3.34) for the light-polymerizing mode and 1.57 (IQR: 0.41) for the dual-polymerizing mode, while the median  $\Delta E^*_{00}$  was 1.65 for the light-polymerizing mode (IQR: 2.34) and 1.18 for the dual-polymerizing mode (IQR: 0.25). The thresholds for clinically acceptable color changes  $\Delta E^*_{ab}>3.46$  and  $\Delta E^*_{00}>2.25$  were found for both curing modes. Marginal discoloration was observed from the 2-year assessment.

**Conclusions.** The color stability of ceramic laminate veneers was similar for both of the polymerizing modes for all evaluated periods. Marginal discoloration increased over a 2-year period for both the light- and the dual-polymerizing modes. (J Prosthet Dent 2017;118:604-610)

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## Clinical Implications

Clinicians should consider that color changes beyond the threshold of clinical acceptability and slight marginal discoloration are observed for a portion of the veneers regardless of the activation mode of the cement (light- or dual-polymerized).

The luting agents available for ceramic restorations can be auto-, light-, or dual-polymerizing resin cement. *In vitro* studies have indicated that dual-polymerizing resin cements undergo greater color alteration than light-polymerizing cements, which is usually attributed to the oxidation of aromatic tertiary amines present on the dual cements as accelerators of the autopolymerizing reaction.<sup>1,9,12-17</sup> The presence of unreacted double-bonds, composition of monomers used in the matrix, filler size and content, water absorption, and environmental factors may also cause color instability in resin cements.<sup>2,18-20</sup>

Artificially accelerated aging and water storage may help predict cement color changes over time. However, in clinical situations, the restorative materials are subjected to numerous dynamic conditions in the oral environment, including temperature variations, continuous humidity, food colorants, and mechanical loading.<sup>7,18</sup> The authors are unaware of published clinical studies that have assessed the color change of the resin cements used for the adhesion of ceramic laminate veneers.

The purpose of this randomized clinical trial was to evaluate the color alteration and marginal discoloration of a dual-polymerizing and a light-polymerizing cement used to cement ultrathin ceramic laminate veneers. The hypotheses were that the polymerizing mode would show no influence on color stability and that the use of light- or dual-polymerizing cement would not influence marginal discoloration.

## MATERIAL AND METHODS

This double-blind, split-mouth randomized clinical trial was approved by the Ethical Committee (CAAE: 13408513.9.0000.5346) and performed in accordance with the Consolidated Standards of Reporting Trials (CONSORT) statement (protocol is available at <http://www.ensaioclinicos.gov.br/rg/RBR-25rc6q/>). Written informed consent was obtained from the 10 participants included in the study. All participants were postgraduate Oral Science students who met the following inclusion criteria: good general and oral health; absence of orthodontic appliances; absence of posterior reverse articulation; absence of noncarious cervical lesions; vital maxillary second premolars without restorations and with color homogeneity in relation to adjacent teeth; and

a minimum 6-mm diameter for the area of the buccal surface of the maxillary second premolars (slightly larger than the 5 mm spectrophotometer tip). Participants with the following characteristics were excluded from the study: gingival recession on the buccal surface of the maxillary second premolars; dental sensitivity to air blast; enamel or dentin defects; tetracycline staining; unilateral or bilateral reverse articulation; mandibular prognathism; maxillary retrognathism; and smokers. Sample size calculation was performed based on a color difference of 3.0 between the means of the groups and a standard deviation of  $\pm 1.7$ .<sup>15</sup> Significance level and statistical power were defined as 5% and 80%, respectively, and a possible loss to follow-up was taken into consideration.

Following clinical and radiographic examination and cold pulp sensitivity testing to verify vitality, the participants answered a questionnaire adapted from Hedric et al<sup>21</sup> regarding the intake frequency of potentially pigmented food and beverages. The questionnaire was validated by comparison with 7-day dietary intake records, using weighted kappa to verify whether participants' answers reflected their habits. The results and validity assessment of the questionnaire are displayed in Table 1. Agreement between the questionnaires and dietary records was perfect ( $K=1$ ) or almost perfect ( $K>0.81$ ) for all items, except for tomato sauce, which was substantial ( $K=0.80$ ), and for colored juices, which was moderate ( $K=0.47$ ).<sup>22</sup>

No tooth preparation was performed. Maxillary arch impressions were made with polyvinyl siloxane (Express; 3M ESPE) with the double-mix technique, and Type IV gypsum (GC Fujirock EP; GC America) casts were obtained. Two 0.3-mm-thick laminate veneers were fabricated by a single dental technician for the buccal surface of the participants' left and right maxillary second premolars, using a high-translucency lithium disilicate glass-ceramic (IPS e.max Press, shade B1; Ivoclar Vivadent AG). The laminate veneers were placed 0.5 mm from the gingival margin, following the anatomy of the teeth and extending slightly to the proximal and occlusal surfaces without interfering with the proximal contacts or occlusion. The margins were beveled to have finish lines at the tooth level without overcontouring. The second premolars were selected because they are in a posterior area but are still visible and accessible for color evaluation.

The polymerization mode was randomized for each side according to a software-generated randomization list (Random.org Integer Generator; <http://www.random.org>). Randomization was concealed by sequentially numbered, opaque, sealed envelopes containing the polymerization mode (light- or dual-polymerizing) and side (left or right). The envelopes were prepared by an investigator (V.F.W.) with no involvement in the trial. For each patient, a researcher (M.M.M.) who was not involved in the cementation and evaluation opened the envelope

**Table 1.** Intake frequency of potentially pigmenting food and beverages and validity assessment<sup>a</sup>

Food or Beverage Type	Never	Less than Once per Week	Once per Week	2-3 Times per Week	4-6 Times per Week	Once per Day	Twice per Day	3+ Times per Day	Kappa Value
Coffee	2	0	0	2	1	2	2	1	0.84
Dark beer	8	2	0	0	0	0	0	0	1
Black tea	8	0	1	0	0	0	1	0	0.91
Colored tea	3	2	1	3	1	0	0	0	0.87
Mate <sup>b</sup>	1	1	1	1	2	1	3	0	0.92
Cola-based soda	1	0	1	6	2	0	0	0	0.80
Colored soda	4	4	0	2	0	0	0	0	0.89
Colored juice	2	3	0	4	0	1	0	0	0.47
Coffee cough drop	9	0	0	1	0	0	0	0	0.85
Colored cough drop	7	2	0	1	0	0	0	0	0.90
Beet	5	0	1	4	0	0	0	0	0.92
Chocolate	1	1	0	6	1	1	0	0	0.84
Raw carrot	2	2	2	3	0	1	0	0	0.88
Gelatin	3	6	1	0	0	0	0	0	1
Molasses	9	1	0	0	0	0	0	0	1
Colored medicines	9	1	0	0	0	0	0	0	1
Saffron sauce	9	1	0	0	0	0	0	0	0.91
Tomato sauce	0	3	1	5	0	1	0	0	0.80
Colored grape	7	3	0	0	0	0	0	0	1
Red wine	6	4	0	0	0	0	0	0	1

<sup>a</sup>Data show assessment of agreement between questionnaire and dietary records. <sup>b</sup>Infused drink commonly consumed in southern Brazil and other countries.

and informed the operator (L.G.M.) of the cementation mode and side. The intaglios of the laminate veneers were treated with 10% hydrofluoric acid (Condicionador de Porcelanas; Dentsply Sirona) and a silane (Monobond S; Ivoclar Vivadent AG). Before cementation, the maxillary second premolars were isolated, the enamel pumiced (Pedra Pomes; Biodinâmica), and the gingival displacement cord (Retraflex retraction cord 000; Biodinâmica) placed in the gingival sulcus. The tooth was etched with 37% phosphoric acid (Condac 37; FGM), rinsed, and dried. The adjacent teeth were isolated with polytetrafluoroethylene tape (Polyfita; Seal Tape), and the light-polymerizing adhesive (Tetric N Bond; Ivoclar Vivadent AG) was applied and photoactivated (Radii-cal; SDI) for 20 seconds. The laminate veneers were cemented with the transparent shade of cement (Variolink II; Ivoclar Vivadent AG) (Tables 2, 3). One side underwent dual-polymerization (using both the base and the catalyst in a 1:1 ratio), whereas the contralateral side underwent light-polymerization (using only the base) (Fig. 1A). Photoactivation was performed for 60 seconds on both groups. The same researcher (M.M.M.) that opened the envelope spatulated the cement and handed it to the operator (L.G.M.) so that the participant and operator were blinded to the polymerization mode. The second cementation was performed on the contralateral side with the remaining polymerization mode.

Color and marginal staining were evaluated at 24 hours (baseline) and at 2, 6, 12, and 24 months after cementation by a blinded evaluator (A.M.E.M.), using a clinical spectrophotometer (Vita Easyshade; Vita Zahnfabrik).

**Table 2.** Variolink II chemical composition

Base Plus Catalyst	Composition
Monomer	Bis-phenol-A-diglycidylmethacrylate (Bis-GMA); Urethane dimethacrylate (UDMA); triethyleneglycol dimethacrylate (TEGDMA)
Inorganic fillers	Barium glass, ytterbium trifluoride, barium and aluminium fluorosilicate glass and spheroid mixed oxide
Additional contents	Benzoyl peroxide, catalysts, stabilizers and pigments.

**Table 3.** Variolink II composition by weight (%)

Composition	Base	Catalyst
Dimethacrylates	26.3	22.0
Inorganic fillers	73.4	77.2
Catalysts and stabilizers	0.3	0.8
Pigments	<0.1	<0.1

Individualized light-polymerizing acrylic resin guides (Elite LC Tray; Zhermack) with a 6-mm-diameter window were positioned on the buccal surface of the second premolars to standardize the positions for the color evaluations (Fig. 1B). The color measurements were recorded in the CIELab system, which defines color on 3 axes: L\*, lightness, ranging from 0 (black) to 100 (white); and a\* and b\*, chromatic characteristics ranging from red (+a\*) to green (-a\*) and yellow (+b\*) to blue (-b\*).<sup>7,16,23-25</sup> The color was measured 3 times, and the mean L\*, a\*, and b\* values were calculated. The variation of each coordinate between the first and subsequent measurements was calculated as follows:  $[\Delta L^* = L^*_{\text{final}} - L^*_{\text{initial}}]$ ,  $[\Delta a^* = a^*_{\text{final}} - a^*_{\text{initial}}]$ , and  $[\Delta b^* = b^*_{\text{final}} - b^*_{\text{initial}}]$ .



**Figure 1.** A, Ceramic laminate veneer after cementation. B, Guide for color measurement: window placed on buccal surface to ensure reproducibility of spectrophotometer readings.

The CIELab color change ( $\Delta E^*_{ab}$ ) was calculated according to the following formula<sup>1</sup>:

$$\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

Color differences were also calculated using the CIEDE2000 formula as follows<sup>26</sup>:

$$\Delta E^*_{00} = \left[ (\Delta L' / k_L S_L)^2 + (\Delta C' / k_C S_C)^2 + (\Delta H' / k_H S_H)^2 + R_T (\Delta C' / k_C S_C) (\Delta H' / k_H S_H) \right]^{1/2},$$

where  $\Delta L'$ ,  $\Delta C'$ , and  $\Delta H'$  are the differences in lightness, chroma, and hue, respectively, between the baseline and the subsequent color readings;  $R_T$  is the rotation function corresponding to chroma and hue difference interaction in the blue region;  $S_L$ ,  $S_C$ , and  $S_H$  are weighting terms for adjustment of the total color difference for variation in perceived magnitude with variation in the location of the color coordinate difference between 2 color measurements; and  $k_L$ ,  $k_C$ , and  $k_H$  are correction terms for the experimental conditions.<sup>13</sup>

Marginal staining was classified according to modified U.S. Public Health Service guidelines<sup>27</sup>: Alfa, absence of marginal discoloration; Bravo, discoloration on less than half of the circumferential margin; and Charlie, discoloration on more than half of the circumferential margin.<sup>28</sup>

The normal distribution and homoscedasticity of the data were investigated using the Shapiro-Wilk and

**Table 4.** Mean  $\pm$ SD CIELab values for ceramic laminate veneers luted with light-polymerizing and dual-polymerizing cement

Cement	2 months	6 months	12 months	24 months
$\Delta L^*$				
Light-polymerizing	-0.13 ( $\pm 3.43$ )	-0.62 ( $\pm 2.65$ )	0.84 ( $\pm 2.74$ )	0.06 ( $\pm 3.5$ )
Dual-polymerizing	-1.15 ( $\pm 3.47$ )	-1.43 ( $\pm 1.37$ )	0.45 ( $\pm 3.48$ )	0.02 ( $\pm 2.6$ )
$\Delta a^*$				
Light-polymerizing	0.12 ( $\pm 0.28$ )	-0.01 ( $\pm 0.23$ )	0.30 ( $\pm 0.35$ )	0.01 ( $\pm 0.36$ )
Dual-polymerizing	0.33 ( $\pm 0.43$ )	0.16 ( $\pm 0.42$ )	0.63 ( $\pm 0.35$ )	0.3 ( $\pm 0.41$ )
$\Delta b^*$				
Light-polymerizing	-0.01 ( $\pm 0.99$ )	-0.52 ( $\pm 1.62$ )	0.32 ( $\pm 1.24$ )	0.48 ( $\pm 1.6$ )
Dual-polymerizing	-0.05 ( $\pm 1.72$ )	-0.20 ( $\pm 1.55$ )	0.40 ( $\pm 1.30$ )	1.05 ( $\pm 1.43$ )

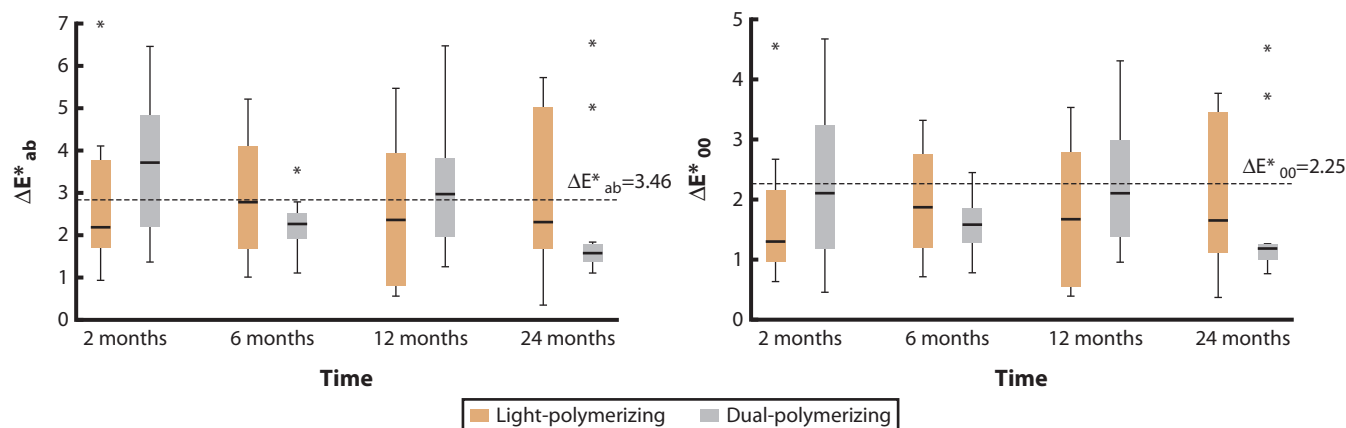
Levene tests. After the normal distribution and equality of variances were verified,  $\Delta L^*$ ,  $\Delta a^*$ , and  $\Delta b^*$  were subjected to paired *t* tests. Because not all data had a normal or homoscedastic distribution, the medians and interquartile ranges (IQR) were calculated for  $\Delta E^*_{ab}$  and  $\Delta E^*_{00}$ , and a nonparametric Wilcoxon test was performed. Marginal discoloration was compared using a McNemar test ( $\alpha = .05$  for all tests).

## RESULTS

No participant was lost to follow-up. No statistical differences were found between the light-polymerizing and dual-polymerizing groups for all the studied parameters across the evaluated periods ( $P > .05$ ). Table 4 shows  $\Delta L^*$ ,  $\Delta a^*$ , and  $\Delta b^*$  values for each period. At 24 months, the median  $\Delta E^*_{ab}$  was 2.31 (IQR: 3.34, maximum: 5.72, minimum: 0.34) for the light-polymerizing mode and 1.57 (IQR: 0.41, maximum nonoutlier: 1.80, minimum: 1.11) for the dual-polymerizing mode; while the median  $\Delta E^*_{00}$  was 1.65 for the light-polymerizing mode (IQR: 2.34, maximum: 3.76, minimum: 0.37) and 1.18 (IQR: 0.25, maximum non-outlier: 1.25, minimum: 0.76) for the dual-polymerizing mode. Figure 2 shows the boxplots for both groups in each evaluated period.

$\Delta E^*_{ab}$  values  $\geq 3.46$  and  $\Delta E^*_{00}$  values  $\geq 2.25$  were considered clinically unacceptable.<sup>23</sup> At 24 months, 4 teeth from the light-polymerizing group and 2 teeth from the dual-polymerizing group showed an unacceptable color change for both the  $\Delta E^*_{ab}$  and  $\Delta E^*_{00}$  thresholds.

No marginal staining was found in either group until the 6-month follow-up (all restorations were classified as Alfa). At the 12-month evaluation, 2 restorations were classified as Bravo (1 in each group), and, at 24 months, 7 restorations (3 in the light- and 4 in the dual-polymerizing group) were classified as Bravo. The McNemar test did not show a statistical difference in marginal discoloration between the groups ( $P > .05$ ) at the 24-month evaluation. Also, no statistical differences were found between baseline and 24-month marginal discoloration for each group ( $P > .05$ ).



**Figure 2.**  $\Delta E^*_{ab}$  and  $\Delta E^*_{00}$  box plots show median, first and third quartiles, and minimum and maximum values. Outliers are marked as asterisks.

## DISCUSSION

The present results support acceptance of the first hypothesis as the polymerization mode did not influence color alteration throughout the evaluated periods. Marginal discoloration was not significantly different between the light- and dual-polymerizing groups, so the second hypothesis was accepted.

The results are in accordance with those of other studies that used the same cement and also did not find a difference of color alterations between the dual- and light-polymerizing polymerization modes.<sup>6,7,12</sup> However, these findings contradict those of Lu and Powers,<sup>16</sup> who observed that the cement experienced a significant color alteration with dual- and light-polymerizing modes. However, cement thickness in that study was 2 mm, much thicker than used clinically, and the cement was not covered by a ceramic layer, which could affect the color change. Furthermore, artificially accelerated aging was performed for 450 kJ/m<sup>2</sup>, so the specimens were submitted to aggressive conditions of humidity, ultraviolet irradiation, and high temperature.

Dual-resin cements are thought to be more susceptible to color change because of the oxidation of aromatic tertiary amines present in their composition, whereas the higher color stability of light-polymerizing cements is because their component aliphatic amines are less susceptible to the oxidation process.<sup>1</sup> For the Variolink II initiator-activator polymerization system, the base contains aliphatic and aromatic amines, while the catalyst contains benzoyl peroxide that reacts with the aromatic amines to produce chemical polymerization.<sup>6,7,16</sup> According to Ghavam et al,<sup>6</sup> when the base is used by itself for light polymerization only, the aromatic amines have no contact with the benzoyl peroxide present on the catalyst and thus remain intact, but the cement with each polymerization mode contains both amines, which may explain why no differences between the groups were found.<sup>6,7</sup>

Although most color alteration result from oxidation of the amines, cement discoloration may also occur because of extrinsic factors such as environmental conditions, ultraviolet irradiation, humidity, heat, and food pigments and intrinsic factors such as matrix composition, filler size and content, and percentage of residual double bonds.<sup>18</sup> The resin matrix of the cement used in the present study is composed of bisphenol A-glycidyl methacrylate (Bis-GMA), urethane dimethacrylate (UDMA), and triethylene glycol dimethacrylate (TEGDMA). Because UDMA is less susceptible to color change than other monomers because of lower rates of water sorption, some studies associate the stability of the cement color with the presence of UDMA and a reduction in the quantity of TEGDMA (a monomer with increased water uptake).<sup>1,7,18,29</sup> In addition, when light transmission is limited, the resin cements undergo incomplete polymerization. The presence of incompletely converted monomer may explain cement discoloration. Therefore, color stability may also be associated with laminate veneers of high translucency and extreme thinness, which would facilitate complete cement polymerization.<sup>7,18</sup> Another reason for the color stability found in the present study is that any color alteration occurring in the thin cement layers used in clinical situations is less perceptible than similar discoloration occurring in the thicker layers used in laboratory studies.<sup>16,17</sup>

The color coordinates showed slight variations. Positive  $\Delta a^*$  values indicate a reddish color.<sup>13,25</sup>  $\Delta b^*$  presented a change from positive to negative values, which indicates a tendency of yellowing over time. An explanation for the yellowish appearance of a resin material is the presence of Bis-GMA monomer in its formulation. Bis-GMA has an inherent tendency to yellow, especially when exposed to ultraviolet light and heat.<sup>1,20</sup>

Color difference formulas are a valuable instrument to guide the selection of esthetic materials in dentistry.<sup>31</sup> The CIELab color difference formula has been used for most of the studies evaluating the color of dental materials.<sup>23</sup> More

recently, the CIEDE2000 adjusted formula was developed to improve CIELab correction between the computed and perceived color<sup>23</sup> and better determine the perceptibility and acceptability of dental ceramics.<sup>24</sup> In this study, both of the color difference formulas were used to allow comparison with previous studies. It is essential to correlate instrumental color difference values with acceptability and perceptibility to provide accurate clinical interpretation,<sup>23</sup> that is, the clinical relevance of color difference formulas depends on how closely the threshold of color change agrees with human visual judgment.<sup>32</sup> The clinical acceptability thresholds (the smallest color difference acceptable by 50% of observers) used in the present study were based on the findings of Ghinea et al,<sup>23</sup> as they determined thresholds for ceramics, using both the CIE-Lab and the CIEDE2000 formulas.

Across all evaluation periods, a portion of restorations showed  $\Delta E^*_{ab} > 3.46$  and  $\Delta E^*_{00} > 2.25$ <sup>23</sup> for both the light- and dual-polymerizing modes (Fig. 2). Lu and Powers<sup>16</sup> also observed that the color alteration of the cement used in this study, with dual- and light-polymerized modes, was considered clinically unacceptable after artificially accelerated aging. Perceptible color alteration of dual-polymerizing disks of the cement was also observed in the studies by Koishi et al,<sup>11</sup> Tanoue et al,<sup>19</sup> and Smith et al.<sup>15</sup> However, because water sorption in the polymer matrix alters the cement refraction index, the color change found in these studies may be attributed in part to the hydrolytic degradation resulting from the specimens' aging during the storage in distilled water.<sup>11</sup> Another factor may be the thickness of the cement disks used in these studies (1 and 2 mm). In the clinical environment, only the cement margin is exposed to the oral environment, as the rest of it is covered by the ceramic restoration. Previous studies evaluating the color stability of ceramic disks cemented on substrates found unacceptable color changes for light- and dual-polymerizing cements after thermocycling<sup>13</sup> and a perceptible color change for dual-polymerizing cements after water storage.<sup>12</sup>

Marginal discoloration was not detected until 1 year after the procedure and then in 10% of the restorations. The percentage was 35% at the 2-year color assessment. Water sorption of the resin cement and pigmentation from food and beverages may cause marginal discoloration,<sup>8</sup> and thus the longer the cement is exposed, the higher the probability of staining. The intake questionnaire showed that the most frequently consumed substances were coffee and a Brazilian beverage, mate, which are possibly related to the marginal discoloration. The presence of marginal staining is in agreement with previous reports.<sup>8,30</sup> All instances were classified as Bravo, which represents slight staining in a small area. No restoration was classified as Charlie, which represents staining in more than 50% of the circumferential margin,

probably because of the laminate veneers' intimate adaptation to the tooth structure and the fact that the margins were located in a way that provided adequate access for cement finishing and polishing procedures.<sup>2</sup> Moreover, bonding to enamel is more predictable than to dentin because of its higher mineral content.<sup>4</sup> Proper adhesion to the tooth structure reduces the possibility of microleakage and severe marginal staining.<sup>33</sup>

The present study had some limitations. A standard clinical spectrophotometer was used. Color measurements may be subject to edge loss when such small-aperture devices are used, which is influenced by curved dental surfaces and translucent ceramic measured.<sup>34</sup> In addition, our findings might not extrapolate to the anterior teeth as they would presumably be more exposed to environmental ultraviolet light, which can induce the oxidation of tertiary amines.<sup>16</sup> Furthermore, the study group was composed exclusively of dentists, who are possibly more conscientious with their oral hygiene than the general population, which may restrict generalization of the findings. It would be desirable that a wider variety of cements was evaluated using other populations in future studies.

## CONCLUSIONS

Based on the findings of this randomized clinical trial, the following conclusions were drawn:

1. The light- and dual-polymerizing modes presented similar color changes for all evaluated periods (2, 6, 12, and 24 months).
2. Color alteration beyond clinically acceptable thresholds was observed for both polymerizing modes. At 24 months, 40% and 20% of restorations presented unacceptable color changes for light- and dual-polymerization modes, respectively.
3. Marginal discoloration was observed from 1 year. At 24 months, 40% and 30% of veneers presented slight marginal discoloration for light- and dual-polymerization modes, respectively.

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