Influence of Activation Mode of Resin Cement on the Shade of Porcelain Veneers

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Abstract

Purpose: The aim of this study was to evaluate the influence of resin luting cement’s activation mode in the final shade of porcelain veneers after accelerated artificial aging (AAA).

Materials and Methods: Porcelain veneers (IPS Empress Esthetic) were produced using a standardized shade (ET1) and thickness (0.6 mm). Twenty bovine teeth were collected, prepared, and divided into two groups: group I (n = 10)—light-cured group, only base paste was applied to the veneers; group II (n = 10)—dual-cured group, in which the same base paste used in group I and a transparent catalyst were proportionally mixed for 20 seconds and then applied to the veneers. The specimens were light-cured for 60 seconds each and were next subjected to AAA. They were submitted to color readings with a spectrophotometer in three instances: in the tooth surface (only the substrate), after the cementation and polymerization of the veneers, and after the AAA. The values of L*, a*, and b* were obtained and the total color change was calculated (ΔE*). Values obtained were subjected to statistical analysis, with a significance of 0.05.

Results: There were no significant differences between dual- and light-cured modes considering ΔE*, L*, a*, and b* values obtained after aging (p > 0.05). Within the dual-cured mode there were no significant differences in ΔE*, L*, a*, and b* values (p > 0.05).

Conclusion: No relevant differences were found between the two activation modes in color change. When submitted to aging, dual- and light-cured modes of the resin cement showed visually perceptible (ΔE* > 1.0) color changes; however, within the threshold of clinical acceptance (ΔE* > 3.3).

Keywords
Dental veneers; resin cements; color perception tests; polymerization; aging.

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Porcelain laminate veneers have become one of the most predictable, most esthetic, and least invasive modes of treatment. Several recent advances in dental bonding technology, resin cements, and ceramic materials have made it possible to produce porcelain laminate veneers with thicknesses ranging from 0.1 to 0.7 mm requiring minimum or no preparation of the tooth structure. The shade of a porcelain laminate veneer is determined by several factors, including the color and thickness of the porcelain laminate veneer, the thickness and the color of the luting cement, and the color of the underlying tooth structure.

Resin cements are generally used for the cementation of all-ceramic restorations as they provide adequate esthetics, low solubility in an oral environment, high bond strength to tooth structures, superior mechanical properties, and support for ceramics. Resin cements may be either chemical-, light-, or dual-cured. Light-cured cements are generally the material of choice whenever possible because of their enhanced color stability and their ability to allow the operator to control the working time. The chemical cure depends on initiators, such as aromatic tertiary amines, that could compromise the color stability of the cemented restorations over time.

Artificial accelerated aging (AAA) has become a reliable method of simulation of oral conditions for a relatively long service time. The manufacturer of the AAA device estimates that 300 hours of weathering is equivalent to 1 year of service, and that the color change produced by AAA is induced in the first 100 to 300 hours of weathering.
the process. According to the literature, color alteration occurs in the first 300 hours of the aging process, as the composite’s water sorption stops with the saturation and stabilization of the polymeric chains.\textsuperscript{9,18,20}

Color measuring devices such as spectrophotometers have become popular because they offer accuracy, standardization, and numerical expression of color.\textsuperscript{21} In these systems, the location of a particular shade in the color space is defined by three coordinates: $L^*$, $a^*$, and $b^*$.\textsuperscript{4,22} These coordinates can then be used to assess the total color change ($\Delta E^*$).\textsuperscript{5} Usually, $\Delta E^*$ values lower than 1.0 are considered undetectable by the human eye, values between 1.0 and 3.3 are considered visible to skilled operators, but clinically acceptable, and $\Delta E^*$ values greater than 3.3 are considered visible to nonskilled people and as such, clinically unacceptable.\textsuperscript{1,10,11,16,17}

Dental restorative materials must withstand widely varied conditions in the mouth, including temperature changes, continuous exposure to moisture, and mechanical use of the restoration.\textsuperscript{23} Studies conducted under accelerated aging conditions allow one to predict the physical behavior of dental composites over time, including color changes.\textsuperscript{9,16,17,22,23} Considering the importance of the color stability of a porcelain laminate veneer for its long-term success, the aim of this study was to evaluate the influence of the activation mode of a resin luting cement in the final shade of porcelain veneers after AAA. The null hypothesis of the present study was that there was no difference in the color change of porcelain laminate veneers when cemented with dual- or light-cured modes of resin cement after AAA.

**Materials and methods**

A total of 20 bovine teeth (substrate) were collected, prepared, and randomly divided into two groups. The teeth were stored in 0.2% Thymol solution at 4°C for a week, the roots were removed, and the buccal face was polished using abrasive paper (600 grit) to obtain a flat enamel surface for the cementation of the laminates. No additional preparation was made to simulate a clinical situation of minimal wear. Porcelain laminate veneers (IPS Empress Esthetic, Ivoclar Vivadent, Schaan, Liechtenstein) were produced using a standard shade (ET1) and thickness (0.6 mm). Initially, a wax pattern was made (11 mm width, 8 mm thickness) (VKS Wax gray; Yeti Dental Produkte, Engen, Germany). Porcelain tablets in color ET1 were injected to obtain a ceramic block. Then, the blocks were cut with a diamond blade (Buehler, Lake Bluff, IL) in a cutting machine (Isomet; Buehler) at a speed of 250 rpm to obtain 1 mm thick disks. Finally, the porcelain disks were manually polished with humid abrasive paper: 800- (medium) and 1200-grit (thin) (3M ESPE, St. Paul, MN) to obtain laminates with 0.6 mm thickness. The thickness standardization was registered with a digital electronic caliper (Mitutoyo Corporation, Tokyo, Japan). This shade of porcelain was selected because it is a light color, and hence, more translucent. The resin cement used in this study was Variolink II—base paste: Yellow and catalyst: Transparent (Ivoclar Vivadent) for 30 seconds as instructed by the manufacturer. After washing thoroughly with water for 60 seconds and drying, the dual-cured adhesive Excite F DSC (Ivoclar Vivadent) was applied for the dual-cured group, and the light-cured adhesive Excite F (Ivoclar Vivadent) was applied for the light-cured group, each one for 10 seconds, dried with light air spray and light-cured with LED (LED radii-cal, SDL Victoria, Australia) for 20 seconds. The veneers were etched with 10% hydrofluoric acid (Dentsply, Petrópolis, Brazil) for 60 seconds and then washed with water. Silane (Monobond-S, Ivoclar Vivadent) was applied for 60 seconds in the etched surface of the veneer. After drying with air spray, the adhesive was gently applied, dried with air spray, and light-cured for 20 seconds.

Group I ($n = 10$) represented the light-cured specimens (base only). Therefore, only base paste was applied in the veneers, taken to the teeth surface, and pressed for 40 seconds using a special appliance that allowed standardization of the cementation pressure (1 kg) and attempted to also standardize the film thickness throughout the study. Although the film thickness was not measured directly, it was assumed that it was relatively uniform due to the uniform loading conditions. Group II ($n = 10$) represented the dual-cured specimens (base + catalyst). Thus, the base and catalyst pastes were proportionally mixed for 20 seconds and applied to the veneers. Then the same steps described for group I were followed. For both groups, the specimens were then light-cured for 60 seconds each: 20 seconds on each proximal side of the tooth while it was under the 1 kg appliance, and 20 more seconds out of the appliance, with the tip of the light source placed on the top and in contact with the porcelain laminate veneers (500 mW/cm²).

The specimens were next subjected to AAA (Accelerated Aging System for Non-Metal Materials, UV-B/Condensation; Adevrin-Comexim Industry, São Paulo, Brazil). The specimens were placed in aluminum plates and exposed to 8 UVB light sources with a radiation of 280/320 nm, at a distance of 50 mm, in a condensation chamber. The program was set for 4 hours of UVB exposure at 50°C, and 4 hours of condensation at 50°C, for a maximum of 400 hours.

Color measurements were made by an operator who was not aware of which group was being read. These readings were carried out using an “Easy Shade” Vita probe spectrophotometer (Vita Easy Shade, Vita, Bad Sackingen, Germany). Spectrophotometers measure CIE-LAB values giving a numerical representation of a 3D measure of color. The $L^*$ describes the lightness, $a^*$ value defines the color on the red-green axis, and $b^*$ on the yellow-blue axis. The specimens were submitted to color readings in three instances: in the substrate, after the cementation and polymerization of the cement, and after the AAA. Measurements were repeated three times for each specimen in each condition. A silicone jig was made to assure that all the readings were made in the central part of every specimen and in the same place. The readings were made against a standard white background (Standard for 45°, 0° Reflectance and Color; Gardner Laboratory Inc., Bethesda, MD) and the spectrophotometer was calibrated before each specimen measurement.
Table 1  Means and standard deviations (±S.D.) of ΔE* for each curing mode

<table>
<thead>
<tr>
<th>Groups</th>
<th>ΔE*1</th>
<th>ΔE*2</th>
<th>ΔE*3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light-cured</td>
<td>28.30 ± 6.42ΔA</td>
<td>3.34 ± 0.53ΔA</td>
<td>28.87 ± 6.25ΔA</td>
</tr>
<tr>
<td>Dual-cured</td>
<td>26.03 ± 6.99ΔA</td>
<td>3.02 ± 1.04ΔA</td>
<td>24.85 ± 6.65ΔA</td>
</tr>
</tbody>
</table>

Means followed by the same superscript lowercase letter denote no statistical difference among the different ΔE* (ΔE*1, ΔE*2, ΔE*3) within the same curing mode (p > 0.05). Means followed by the same uppercase letter denote no statistical difference between the curing modes (light- and dual-cured) within each ΔE* (p > 0.05).

To determine the total color change (ΔE*), the formula below was used:

$$ΔE* = [(ΔL*)^2 + (Δa*)^2 + (Δb*)^2]^{1/2}$$

where ΔL* is the variation of L*, Δa* is the variation of a*, and Δb* is the variation of b*.

Three ΔE* values were obtained in this study. The first ΔE* represented the comparison of the values measured in the substrate and the ones obtained after the cementation (called ΔE*1). The second ΔE* compared the coordinates obtained after cementation with the ones measured after AAA (ΔE*2). The last ΔE* compared the substrate and the values obtained after the specimens were subjected to AAA (ΔE*3).

Values obtained for L*, a*, b*, and ΔE* were subjected to statistical analysis in SPSS 17.0 for Windows (SPSS Inc., Chicago, IL) with a significance level of 0.05 (p < 0.05). For paired comparisons of independent samples, the T-test was applied for parametric samples, and the Mann-Whitney test was used for the nonparametric ones. In comparisons of multiple variables, ANOVA and Tukey were used for the parametric samples, and for nonparametric samples, the Dunn method and the Kruskal-Wallis test were applied.

**Results**

The means, standard deviations, and sums of ranks for ΔE* and for L*, a*, and b* are shown in Tables 1 and 2, respectively. The sums of ranks are shown only for the nonparametric samples in parentheses in Table 2.

There were no significant differences between the curing modes considering the different ΔE* obtained with the values of substrate—after cementation (ΔE*1), after cementation—after AAA (ΔE*2), and substrate—after AAA (ΔE*3) (p > 0.05). When comparing the color changes (ΔE*) within the same curing mode, there were no significant differences between ΔE*1 and ΔE*2 in dual- or light-cured modes of the cement (p > 0.05); however, the ΔE*3 values for the light-cured and the dual-cured groups were significantly lower than the others (p < 0.05).

The results for L*, a*, and b* are shown in Table 2. There were no significant differences in L*, a*, and b* measured in the substrate among specimens (p > 0.05). After cementation, there were significant differences between the curing modes for a* values, where the light-cured specimens presented higher values of a* than the dual-cured ones (p < 0.05). For L* and b*, there were no significant differences between curing modes after cementation (p > 0.05). After AAA, there were no significant differences in L*, a*, or b* between the curing modes (p > 0.05).

When comparing the values of a* and b* within the light-cured group, there were significant differences when comparing the values obtained in the substrate with the ones after cementation, and when comparing substrate with after AAA (p < 0.05). L* values obtained after cementation differed significantly from the others (p < 0.05), presenting the highest L*.

For comparisons within the dual-cured group, L*, a*, and b* values showed significant differences when comparing measurements in the substrate with after cementation and when comparing substrate with after AAA (p < 0.05). There were no significant differences in the coordinates obtained after cementation and the ones obtained after AAA (p > 0.05).

**Discussion**

The final color of translucent ceramic restorations is determined by the thickness of the porcelain, the thickness and color of the luting agent, and the color of the underlying tooth structure.\(^5\,8\,12\)

In this study, bovine teeth with minimum preparation (without exposing dentin) were used as substrate, as porcelain veneers

Table 2  Means and standard deviations (±S.D.) of L*, a*, and b* values for each measurement. The sums of ranks, for specimens with no-parametric distribution, are shown in parentheses

<table>
<thead>
<tr>
<th>Substrate</th>
<th>After cementation</th>
<th>After AAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light-cured</td>
<td>Dual-cured</td>
<td>Light-cured</td>
</tr>
<tr>
<td>L*</td>
<td>74.59 ± 11.73ΔA</td>
<td>69.92 ± 7.21ΔA</td>
</tr>
<tr>
<td></td>
<td>(109.00)</td>
<td>(101.00)</td>
</tr>
<tr>
<td>a*</td>
<td>7.67 ± 3.45ΔA</td>
<td>8.35 ± 3.75ΔA</td>
</tr>
<tr>
<td>b*</td>
<td>47.56 ± 6.00ΔA</td>
<td>43.78 ± 6.48ΔA</td>
</tr>
</tbody>
</table>

Means in the same row with same superscript lowercase letter denote no statistical difference between curing modes in the same measurement period (substrate, after cementation or after AAA) (p > 0.05).

Means in the same row with same superscript capital letter denote no statistical difference among measurement times within the same curing mode (light— or dual—cured) (p > 0.05).
are etched mostly to enamel. The L*, a*, and b* measurements in the substrate were similar in all groups, showing a standardization of the background used in this study. As the ceramics used for all specimens were the same shade and thickness, it can be concluded that any color change noticed occurred in the resin cement layer.

In the present study, the luting agents, in very little thickness, were bonded to a 0.6 mm ceramic disk and a thin enamel substrate to reproduce the clinical condition. The film thickness should have been measured directly to ensure that cements were being compared on an equal basis, rather than assuming an equal load would produce an equal thickness. During polymerization, it is easier for the curing light to pass through more translucent materials than through more opaque ceramics, granting a higher degree of conversion in the cement underneath it. The ceramic used in this study has translucent characteristics, and is also used in very low thicknesses to provide a higher degree of conversion and indicate any significant color changes in the luting material.

It has been demonstrated that dual-cured resin cements show unstable color characteristics, as the additional chemicals necessary for dual polymerization can cause the color of the cements to change over time. However, in this study after luting the laminates, there were no differences in any coordinates between the curing modes of the cement tested, except from the a* coordinate: the light-cured mode showed a tendency to red shades, with a higher a* value. A probable explanation for this is the more efficient polymerization reaction in the dual-cured cement, as it relies on two processes: the self-cured and the light-cured. That might enhance the degree of cure in these cements when compared to the light-cured ones, with fewer unreacted components and a more steady color.

Considering the literature and the advice of the manufacturer, AAA in this study was conducted for 300 hours, achieving the color changes expected for a long clinical service; however, after AAA, the total color change observed in both curing modes showed no significant differences, accepting the null hypothesis presented. The ∆E* of the dual-cured cement comparing substrate and after aging (∆E*) was 3.0, and the ∆E* of the light-cured one was 3.3, both on the threshold of clinically acceptable, but visible to a skilled operator. The base paste of Variolink II contains both aliphatic and aromatic tertiary amines, and the catalyst paste contains benzoyl peroxide, which reacts with the amine to start the self-curing process. The fact that both groups contained base paste, and therefore, two kinds of amine, can explain why the ∆E* of the different groups did not significantly differ in the current study, in agreement with the findings of Ghavam et al.

Efficient polymerization and a high degree of polymer conversion can influence color stability, because residual monomers existing in the polymeric chain can lead to the formation of colorimetric degradation products (residual amines and unreacted carbon-carbon bonds) in addition to facilitating penetration of solvents from the oral environment into the polymeric network, thus promoting hydrolytic degradation of the newly formed chain. Considering these characteristics, sufficient curing of the specimens can also explain the relative color stability of the groups.

In addition, the physicochemical properties of monomers used in a resin matrix may influence resistance to staining. As reported by the manufacturers, Variolink II contains bis-GMA, UDMA, and TEGDMA. Water uptake by bis-GMA-based resins increases in proportion to the TEGDMA concentration and decreases with the partial substitution of TEGDMA by UDMA. Water sorption is reported to be a factor affecting short-term discoloration, changing the refractive index of the composite. The presence of UDMA in the matrix of Variolink II may explain the acceptable values of ∆E* found in this study, as none of the curing modes showed clinically unacceptable color changes.

The dual-cured group showed color stability, with no differences between any of the coordinates obtained before and after AAA; however, as the L* value decreased, the light-cured group showed a loss of lightness with the aging. This finding is in agreement with other studies, where it was suggested that resin-based materials tend to darken after accelerated aging.

According to the results of this study, Variolink II can be used as light- or dual-cured resin cement. These results may be attributed to adequate polymerization beneath the 0.6-mm-thick porcelain laminate veneer. The IPS Empress Esthetic system, which has a very translucent structure compared with other all-ceramic systems, might have affected the polymerization of the resin cement by allowing adequate light through the porcelain laminate veneer. However, the mixing of both pastes gave the cement higher color stability. Thus, the mixture of both pastes (dual mode) is the primary method indicated for this material, as generally the best characteristics are achieved with the mixture of both dual resin cement pastes.

Conclusions

No relevant differences were found between the two activation modes in color change. The current results showed that when submitted to aging, dual- and light-cured modes of the resin cement showed visually perceptible (∆E* > 1.0) color changes; however, within the threshold of clinically acceptable (∆E* > 3.3).

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