BASIC SCIENCE RESEARCH

Effect of Firing on the Color Stability of a Light-Cured Ceramic Stain

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Purpose: **This study evaluated the color stability of four stains of a light-cured porcelain stain system between the light-cured and fired stages.**

Materials and Methods: **Thirty-six ceramometal discs 20 mm in diameter and 2 mm in thickness were cast to provide the substrate on which Ceramco II porcelain was applied. The porcelain was polished to a uniform thickness of 2 mm, and the samples were divided into four groups and assigned a color (yellow, orange, green, or blue). Orbit LC stain was applied in a thin layer and light-cured for 40 seconds. After light-curing, three color readings were made with a Minolta Chroma Meter II. The porcelain discs were then fired in a porcelain oven and three color measurements were again made. The pre- and postfired Commission Internationale de l'Eclairage *L*a*b** values were recorded and the color difference (ΔE) was calculated for each specimen. The clinical significance for the computed ΔE ratings was completed according to previously modified criteria.**

Results: **The results show that the mean ΔE between the light-cured and fired stages of Orbit LC are clinically acceptable. No statistically significant differences ($p < .05$) were observed between any of the four groups.**

Conclusions: **A light-cured porcelain stain system was evaluated for color stability between light-cured and fired stages. Within the conditions of this study, the following conclusions can be made: (1) There was no clinically significant color difference between light-cured and fired stages for the stain colors evaluated; and (2) the final color of the restorations altered with light-cured stains can be predicted before firing.**

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THE BEAUTY of an unrestored tooth results from the combination of light reflected by the enamel and underlying dentin. One of the most difficult tasks faced by the restorative dentist is to simulate that natural beauty with dental porcelain. Communication with the ceramist concerning subtle stains, cracks, or unusual features within or on adjacent natural teeth contributes to the patient's eventual acceptance or rejection of esthetic restorations. A mismatch of porcelain and natural tooth shades is directly affected by the difficult and sometimes crude methods available to convey a patient's tooth shade to the ceramist.

An explanation of the science of color as it relates to successful patient care may be found throughout dental literature.[1-3] The most basic description of color divides it into hue (basic color), value (lightness), and chroma (saturation). Porcelain restorations having a slightly high value and/or a low chroma may be easily modified by custom staining techniques that characterize or modify the color extrinsically.[4,5] The reluctance of practitioners to routinely use these procedures stems from many factors, not the least being an inability to place the stain directly on the porcelain, verify the color intraorally, and then be confident that the final color of the porcelain after firing will be identical.

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A recently developed light-cured, porcelain stain system (Orbit LC; GC America Inc, Chicago, IL) simplifies chairside characterization of porcelain restorations by the dentist. Once the restoration has been characterized and the stain light-cured, it may then be glazed in the dental office or be returned to the ceramist for glazing. It is widely accepted that conventional wet surface colorants achieve their final color only after the firing cycle because of the breakdown of pigments that may occur at firing temperatures.[6-8] Thus, a porcelain stain system allowing placement and firing of custom stains with minimal change in color would be of immense benefit to the dental community.

The purpose of this study was to test the null hypothesis that there is a clinically unacceptable color difference (ΔE) between light-cured and fired states of the Orbit LC porcelain stain system.

Materials and Methods

Thirty-six ceramometal discs (Olympia; J.F. Jelenko Co, Armonk, NY), 20 mm in diameter and 2 mm in thickness, were cast to provide the substrate on which Ceramco II (Ivoclar N.A.; Armhust, NY) porcelains, shade Vita A-3, was applied following the manufacturer's recommended technique and firing schedule. After firing, the glazed porcelain surface was polished on a 200-grit rotating silicon carbide disc, followed by a 600-grit disc (Mager Scientific, Inc, Dexter, MI), to produce a porcelain thickness of 2 mm. The samples were divided into four groups and each group assigned one stain color: yellow, orange, green, or blue. The Orbit LC porcelain stains were mixed as recommended by the manufacturer, and a thin layer of the stain was applied on the polished porcelain surfaces and light-cured for 40 seconds.

A Minolta Chroma Meter II (Model CR-121; Minolta Corp, Osaka, Japan) was utilized for all color measurements. It is a light, compact, tristimulus color analyzer for measuring reflected subject color. Utilizing high-sensitivity silicon photo cells filtered to match Commission Internationale de l'Eclairage (CIE) Standard Observer response, readings are made through the measuring head, processed by the built-in microcomputer, and presented digitally on the custom-designed liquid-crystal display. The measuring head contains a high-power pulsed xenon arc (PXA) lamp, which provides diffuse illumination from a controlled angle for vertical viewing and constant, even lighting on the subject. The meter's double-beam feedback system, using six photocells, detects any slight deviations in the xenon light's spectral distribution, and the microcomputer compensates for them. The head provides a choice of two standard CIE illuminant conditions: Illuminant C (6774K) and Illuminant D_{65} (6504K), which was used for this experiment. The measuring area at the tip of the head is only 3 mm in diameter, allowing readings of the necessarily small samples without cutoff. Light from the PXA lamp is diffused in the mixing chamber and projected onto the sample at a controlled angle of 45°. The light reflected vertically from the sample is collected by the optical cable and sent to the silicon photocells for color evaluation. Specularly reflected light is blocked from reaching the optical cable, enabling more accurate measurement of glossy surfaces.

Prior to experimental measurements, the colorimeter was calibrated to a standard white tile supplied by the manufacturer. Three individual initial color readings were made after the stains were light-cured. Then, a mean CIE $L^*a^*b^*$ value was calculated.[3] Specimen discs were then placed in a porcelain oven, dried for 5 minutes, and preheated for 10 minutes at 550°C. The temperature was then increased to 910°C without a vacuum and held for 1 minute. After firing, three color measurements of each specimen were recorded and mean CIE $L^*a^*b^*$ values were calcualted. With this system, L* becomes value, while a^* and b^* represent hue and chroma, respectively. More specifically, a^* represents the red-green axis and b^* the yellow-blue. Pretreatment and posttreatment CIE $L^*a^*b^*$ color coordinates of each sample were compared with each other using the formula:

$$\Delta E = ((L^*1 - L^*2)^2 + (a^*1 - a^*2)^2 + (b^*1 - b^*2)^2)^{0.5}$$

where ΔE represents the color change between the initial sample with the light-cured stain and that same sample after firing of the stain. L^*1, a^*1, and b^*1 represent pretreatment color coordinates of each sample, and L^*2, a^*2, and b^*2 represent posttreatment color coordinates of each sample. The ΔE was calculated for each sample and the data subjected to statistical analysis. A clinical evaluation of significance for the computed ΔE ratings was completed according to criteria modified from Johnston and Kao,[1] and O'Brien et al[2] (Table 1).

Within the several Orbit LC shade groupings (yellow, orange, green, blue), a one-way ANOVA ($p < .05$) was used to statistically determine differences in ΔE values of the light-cured and fired porcelain samples, ie, yellow was compared with orange, green, and blue; orange was compared with yellow, green, and blue, etc.

Results

The mean ΔE values, SD, and maximum and minimum ΔE values for the experimental groups are

Table 1. Criteria for Color Match

ΔE Units	*Color-Match Rating*
<1	Excellent
<3.7	Clinically acceptable
>3.7	Poor

Note. Adapted from Johnston and Kao,[1] and O'Brien et al.[2]

Table 2. ΔE Between Light-Cured and Fired Stages of Each Stain

Stain Color	Sample Size (n)	Mean ΔE ± SD	Mean Color Match	Minimum ΔE	Maximum ΔE
Yellow	9	1.08 ± 0.49	CA	0.51	2.23
Orange	9	2.08 ± 0.98	CA	0.42	3.33
Green	9	1.70 ± 0.84	CA	0.90	3.44
Blue	9	1.91 ± 0.77	CA	0.83	2.89

Abbreviation: CA, clinically acceptable.

presented in Table 2. The maximum and minimum ΔE values recorded were 3.44 units and 0.5 units, respectively, and all samples were rated as excellent or clinically acceptable. No statistically significant differences ($p < .05$) were observed between any of the groups. The percentage of ΔE distribution and color-match rating between the light-cured and fixed stages is presented in Table 3.

Discussion

The demand for esthetic restorations has increased considerably in recent years. An acceptable shade match with porcelain restorations is often difficult to achieve and continues to present problems for dental practitioners. If the dentist is to expect improved and more consistent results, custom staining procedures of porcelain restorations performed chairside would be a logical choice. Previously, porcelain stains consisted of wet colorants, which require immediate firing after application to the restoration. Thus, the dentist must perform the entire procedure in the office. Manipulating these stains is difficult because of their fluid nature, and the different colorants, when added together, tend to blend. In the present study, the color stability after glazing of a light-cured porcelain stain system was evaluated. Four stains (yellow, orange, blue, and green) were selected from the staining kit. Yellow, orange, and blue were selected because of their common utilization in staining procedures, and also because they have previously been shown with other colorant systems to be consistently less color-stable than other stain colors.[6-8] Throughout the experiment, all stain shades were consistently rated as having either an excellent or a clinically acceptable color match between light-cured and glazed stages. Twenty-two percent of the samples had a ΔE smaller than 1 unit; the remaining samples (78%) had a ΔE of less than 3.7 units, which, according to the criteria utilized, is rated as clinically acceptable. The maximum ΔE obtained was 3.44 units and the minimum was 0.50. There was no statistically significant difference between groups demonstrating equal performance for all color stains evaluated.

Table 3. Percentage of Distribution and Color-Match Rating

ΔE Units	No. of Samples	Percentage	Color Match
<1	8	22.2	Excellent
<3.7	28	77.8	Clinically acceptable
>3.7	0	0	Poor

Note. n = 36.

Crispin et al,[6] by using a similar methodology, assessed the color stability of ceramic stains subjected to glazing temperatures. These results revealed significant color change after glazing for all the conventional ceramic stains evaluated. That study equated a ΔE greater than 2 units as a significant change, and a ΔE greater than 10 units as a very significant change. Some stain shades had a ΔE greater than 10. Yellow and orange stains were consistently less color-stable within all brands. Mulla et al[7] verified the effect of temperature on color stability of two colors (blue and orange) for three different commercial porcelain stains. His results showed no effect on the ΔE caused by the two temperatures tested (1,700° and 1,775°F) or by the technique utilized (overglazed vs autoglazed). The reported ΔE ranges from 4 to 22 units, and blue was consistently less color-stable. Lund et al[8] also assessed color change of 10 Ceramco stains after firing. In his work, the yellow stain was consistently the least color-stable (mean ΔE, 4 units) when compared with all others.

During the present research, the assumption was made that the underlying porcelain had no change between the original color registration and the post-treatment registration solely because of either the light-curing or glazing process. Because each sample served as its own reference point for color change, it was felt that clinical relevancy of the project would be

based on treating the samples in a similar manner to ceramic crowns requiring surface staining.

The results of this study demonstrate that the mean ΔE between light-cured and fired stages of the Orbit LC ranges from excellent to clinically acceptable according to the utilized criteria ($\Delta E > 3.7$ as clinically relevant).[1,2] This finding was consistent for all stain shades evaluated, as well as 100% of the samples (n = 36).

Conclusions

A light-cured porcelain stain system was evaluated for color stability between light-cured and fired stages. Within the conditions of this study, the following conclusions can be made:

1. There was no clinically significant ΔE between light-cured and fired stages for the stain colors evaluated.
2. The final color of the restorations altered with light-cured stains can be predicted before firing.

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