

Evaluation Of The Effect Of Cement Shade And Accelerated Artificial Aging On Color Stability Of Cadcam Resin-Matrix Ceramics: An In Vitro Study

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Abstract

Aim: This study was conducted to examine the effect of cementation and artificial aging on color stability of three resin-matrix ceramic CAD/CAM materials.

Methodology: About 12 x 14 x 1.0 mm rectangular-shaped specimens were prepared from a hybrid ceramic (Vita Enamic), a hybrid resin nano-ceramic (Cerasmart), and a resin nano-ceramic (Lava Ultimate) (n = 30). Specimens of each material were luted with three shades of a resin cement in 0.2 mm thickness (Variolink N; A1, Bleach XL and Transparent), followed by artificial aging step (n = 10). Color coordinates were measured in each step with a colorimeter. Color differences (ΔE_{00}) were calculated from CIEDE2000 formula, and statistically analyzed with one-way ANOVA and paired t-tests.

Results: Artificially aging the specimens resulted in a significant increase in ΔE_{00} regardless of shade and material type ($p < 0.05$). No significant color differences due to artificial aging were detected when the three shades were compared for only Vita Enamic samples ($p > 0.05$). Luting with different shades of resin cement did not result in a statistical difference in ΔE_{00} between the restorative materials ($p < 0.05$) except for Cerasmart luted with Bleach XL ($p < 0.05$); however, artificial aging led to statistically significant differences between the materials when luted with the same shade of the resin cement ($p < 0.05$).

Conclusion: The final color of resin-matrix ceramics is affected by the resin cement shade and artificial aging.

Keywords: Artificial aging, CAD/CAM resin-matrix ceramics, Color stability, Resin cement.

INTRODUCTION

In dentistry, the popularity of chairside computer-assisted design and computer-assisted manufacturing (CAD-CAM) systems has increased worldwide. Conventional impressions and temporary restorations are eliminated with CAD-CAM systems, and the restoration can be completed in a single visit within a short time.¹ As a result of the continuous development of CAD-CAM technology and increasing patient esthetic expectations, various machinable indirect dental esthetic restorative materials with different mechanical and optical properties are being developed continuously.^{2,3} The standardized and controlled manufacturing process of CAD-CAM blocks under optimal conditions provides homogeneous and defect-free materials.⁴⁻⁶ Chairside CAD-CAM materials include acrylics, resin-based composites, silicate ceramics, oxide ceramics, and resin-matrix ceramics. Appropriate selection of the materials depends on the indications of these materials as well as the necessary specific functional and esthetic requirements for clinical success.⁷ Esthetic appearance, mechanical properties, biocompatibility,

durability, and resistance to staining of ceramic materials are superior to those of composites.^{8,9} However, ceramic materials tend to be more brittle, creating a risk of marginal fractures, delamination, and chipping.⁴⁻¹⁰ Meanwhile, composite materials are easy to finish, polish, and repair, and they have low abrasive properties to the antagonist enamel. The milling procedure of composite blocks takes less time and causes less wear on the milling instruments compared to ceramic blocks.^{6,10} Thus, to combine the advantages of ceramics and composites, resin-matrix ceramic materials have been improved for chairside restorations.^{2,4} Matching the optical properties of restorations with natural teeth is a major challenge in esthetics. The properties of the esthetic restorative material, such as thickness and composition, may affect the final color of the restoration, as much as the color of the underlying tooth/abutment structure and luting cement.¹¹⁻¹⁵ The translucency of laminate veneer restorations allows more light to enter and scatter, causing the underlying structures to have a significant impact on the final color. Hence, the color matching process becomes more complex in veneer restorations.¹⁶ Factors such as thickness, color, type of restoration, and cement color should be considered to eliminate undesirable effects.¹⁷⁻²⁰ The success of such CAD/CAM new blocks relies on the longevity of the fabricated restorations. The mechanical and optical properties are the key factors that determine the preferability of the fabricated material for dental restoration purposes. In earlier studies, the mechanical properties have been well-documented, and it was shown that their mechanical and physical features resembled those of natural dentin and enamel. Sustaining long-term color stability of resin-matrix ceramics remains a challenging critical determinant of the success of a restoration.¹⁸ In this respect, accelerated artificial aging is a suitable method for simulating oral conditions for anticipating color changes in restorative materials over time.⁷ However, to date, long-term behavior of these new materials in terms of color change is seldomly investigated under simulation of oral conditions.

AIM OF THE PRESENT STUDY

This study was conducted to examine the effect of cementation and artificial aging on color stability of three resin-matrix ceramic CAD/CAM material specimens.

METHODOLOGY

The impact of choosing different shades of a resin cement and artificial aging on the final color was tested on three different resin-matrix ceramic CAD/CAM restorative materials: a hybrid ceramic (Vita Enamic, Vita Zahnfabrik, Germany; VE), a hybrid nano-ceramic (Cerasmart, GC, Tokyo, Japan; CS), and a resin nano-ceramic (Lava Ultimate, 3M ESPE, St. Paul, MN, USA; LU). The color of the high translucent CAD/CAM blocks was 1M2 for VE, and A1 for CS and LU, respectively. Accelerated artificial aging was made by utilizing a UV aging machine (BGD 856 UV Light Accelerated Weathering Tester). The specimens were inserted into the molds and remained in the testing device for 300 hours. In weathering chamber, fluorescent UV light simulates the sunlight, while a condensation and water spray system simulate the rain, dew, and water cleaning. The polished surface of each specimen was continuously exposed to the light source from a 10 cm distance and the relative humidity was adjusted as 90%. Each aging cycle was conducted sequentially with UV irradiation for 8 hours at $60^{\circ}\text{C} \pm 3^{\circ}\text{C}$ (level of irradiance: 1.55 W/m^2); a 18 minutes distilled water spraying; and condensation cycle (light off) for 4 hours at $50^{\circ}\text{C} \pm 3^{\circ}\text{C}$. The cycles were repeated with a 120 minutes intervals. A colorimeter (Konica Minolta CR-321, Minolta, Osaka, Japan) was used to determine color coordinates of the samples relative to CIE D65 standard illuminant against a white background. Calibration of the colorimeter was performed with its calibration apparatus prior to each measurement. The CIEDE 2000 (ΔE_{00}) formula was used to quantify color changes among the tested groups.⁵ CIEDE 2000 (ΔE_{00}) and color changes were examined in terms of perceptibility and clinical acceptability thresholds. The perceptibility threshold was taken as $\Delta E_{00}=1.30$; and the clinical acceptability threshold was taken as $\Delta E_{00}=2.25$. The mean color coordinates and color differences values with standard deviations were calculated by using SPSS 21.0 statistical software. One-way analysis of variance (ANOVA) test was performed to identify color changes observed after cementation and after aging for different shades of luting agent on the same material, respectively, and also those of three restorative materials luted with the same shade. Paired t-test was used to determine color differences due to artificial aging on the samples luted with the same shade of resin cement for each restorative material. The significance level for each test was set at 0.05.

RESULTS

The one-way ANOVA results revealed that the luting of the same resin-matrix ceramic material with each shade of resin cement led to significant differences of the color changes. After artificial aging, although there was no statistical difference between the Vita Enamic samples of three shades of resin cement however, this process led to color change when the same shade of luting agent was used. Statistically, a similar behavior of the color change was noted between the subgroups of the Cerasmart samples after cementation. Any statistical difference on color change of each restorative material after cementation was not noted with the same shade of resin cement, except to Cerasmart material luted with BL1, which yielded highest ΔE_{00} value compared to other two restorative materials ($p < 0.05$). With the artificial aging process, ΔE_{00} values of all Cerasmart subgroups significantly increased when compared with the values obtained after cementation ($p < 0.05$), and all of them was found to be not clinically acceptable. On the color change of Lava Ultimate samples, luting value showed larger ΔE_{00} values ($\Delta E_{00} = 4.18$; clinically unacceptable). After artificial aging, ΔE_{00} values significantly increased with unacceptable clinically thresholds for all Lava Ultimate subgroups ($p < 0.05$), respectively. However, artificial aging led to statistical differences of the final color between the resin-matrix ceramic materials for each shade used ($p < 0.05$). These values were higher for Lava Ultimate compared with other two materials, following Cerasmart, with the lowest for Vita Enamic regardless of the shade of luting agent. (Table 1)

Table 1- Results of color differences (ΔE_{00}) of different shades between cementation and artificial aging for the same restorative material

		After Cementation	After Artificial Aging		
Material	Shade	Mean \pm SD	Mean \pm SD	T	p
Vita Enamic	A1	1.51 \pm 0,45	2.01 \pm 0,58	2.06	0.069
	Bleach XL	4.89 \pm 0,67	2.37 \pm 0,45	12.7	0.001
	Transparent	1.27 \pm 0,39	2.20 \pm 0,30	6.76	0.001
Cerasmart	A1	1.25 \pm 0,44	6.19 \pm 0,27	26.7	0.0001
	Bleach XL	5.36 \pm 0,69	6.40 \pm 0,17	4.27	0.002
	Transparent	1.59 \pm 0,48	6.74 \pm 0,39	34.3	0.001
Lava Ultimate	A1	1.52 \pm 0,56	6.97 \pm 0,34	27.8	0.0001
	Bleach XL	4.18 \pm 0,76	7.00 \pm 0,30	11.3	0.0001
	Transparent	1.53 \pm 0,39	7.85 \pm 0,21	57.4	0.0001

*n = 10 specimens per experimental condition, (paired t-test at $p < 0.05$)

DISCUSSION

Refractive index materials can be used as optical coupling agents in dental research because they reduce internal reflection and increase light transmission. Various studies on dental color have used agents such as distilled water, sucrose solution, glycerin, immersion oil, and optical liquids to provide an optical connection between restoration and cement/background. White, black, and gray are neutral colors because they do not have a hue. It has been reported that the shape, size, and direction of the cement affect the CIE color coordinates, and the final color of dental restorative materials mostly depends on the composition of the cement. The color of the resin composite material and optical properties are determined by the resin matrix composition, filler composition, particle size and content, and supplemental additives, including pigments, inhibitors, and activators. Differences in light transmission characteristics of different resin composite colors may affect the clinical appearance of restorations.¹² The esthetic advantages of dental restorative materials largely depend on their translucency properties. The effect of cement and background colors on the color of metal-free restorations has been mainly associated with the translucency property of the restoration. A recent study reported that resin based ceramics (CS) showed higher translucency values than LU and VE. This result may be related to the inorganic content of the materials. High light transmission is allowed because of the absence of opacifying agents in CS. The filler particles in CS are smaller than those in the VE and LU resin-matrix ceramic materials. In addition, the refractive indices of the monomers in the matrix are closer to those of the filler particles in CS.¹⁵ In the current study, the baseline color coordinates for each specimen prepared with three resin-matrix ceramic restorative material were determined by 3D color measurement system, and then repeated after cementation and artificial aging, respectively. CIEDE2000 formula was applied to obtain color changes, in which the perceptibility limit as $\Delta E_{00} = 1.30$ unit and clinically

acceptable limit as $\Delta E_{00} = 2.25$ unit was accepted as stated by Ghinea et al.¹⁹ For each material type, one-way ANOVA results indicated a significant main effect of resin shade and also of artificial aging process on the final color of the same ceramic material. The luting with Bleach XL led to clinically unacceptable color change ($\Delta E_{00} > 2.25$) for each resin-matrix ceramic material; A1 shade luting yielded perceptible color change ($\Delta E_{00} > 1.30$) on the materials of Vita Enamic and Lava Ultimate, whereas luting with transparent shade affected the color of Lava Ultimate and Cerasmart with a perceptible change ($\Delta E_{00} > 1.30$). On the other hand, a comparison of three resin-matrix ceramic materials luted with the same shade of the resin cement did not present any statistical difference on color change after cementation ($p > 0.05$), except to Bleach XL subgroup of Cerasmart. The color differences observed between different shades of resin cements on the same material might be due to the varying amounts of opacity 'ingredients' present in the cement structure. The inorganic fillers within the resin cement represent a phase with a different refractive index from the bulk of the resin-matrix ceramic materials, with subsequent scattering of light. Moreover, degree of chroma may also influence the final color resulting in meaningful differences.³⁻⁹

CONCLUSION

Based on the results presented in this study, it seems that both resin-matrix ceramic type and different shades of the same luting agent affected final color of the specimens, which is crucial in long-term clinical serviceability of restorations. As a limitation, this in vitro study tested the impact of shading and artificial aging while thickness of the restorative materials and the resin cement were kept constant. Future studies which investigate the impact of different thicknesses of the CAD/CAM restorative materials and different brand of the luting agents will provide a deeper insight for predicting the clinical behavior in oral conditions.

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