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Resin Cement and Substrate Color Influence on Color Difference of Hybrid CAD/CAM Restorations

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ORIGINAL RESEARCH ARTICLE

Abstract

The color difference between adjacent teeth and prosthetic restoration can jeopardize the success of a prosthetic restoration. The type of ceramic, the shade of the selected cement and the underlying foundation may affect the optical behavior of the final restoration and can have an important impact on the final esthetic outcome of the treatment. The purpose of this in vitro study was to evaluate the optical behavior of dental ceramics depending on the chosen shade of resin cement and the underlying substrate. Twenty-four ceramic discs (14x12x1 mm, shade A1) were prepared from 2 different CAD/CAM blocks, a nanoceramic resin (Cerasmart, GC Europe) and a hybrid ceramic (Enamic, VITA, Zahnfabrik), both A2 shade. Three composite resin foundation (14x12x4 mm) were fabricated in A1, A3 and A3.5 shade. Color coordinates were recorded with a digital spectrophotometer. The coordinates of the composite resin matrix and the ceramic discs superimposed served as the control group. The ΔE_{ab} formula was used to assess the color difference. Data were subjected to 3-way ANOVA and Tukey significant difference tests. The final color of the restoration is influenced by the underlying substrate and the shade of cement**;** changes to the underlying composite color resulted in modifications of color parameters. This study demonstrated that the underlying tooth abutment color and cement shade can influence the final color of the ceramic restoration.

Key words: CAD/CAM, nanoceramic resin, hybrid ceramic, optical properties.

I. INTRODUCTION

Lately, increased demand for aesthetics has led to the development of all-ceramic systems. The use of computer-aided design (CAD) and computer-aided manufacturing (CAM) has become more and more popular and was developed to obtain easier, faster, and more accurate prosthetic restorations with natural appearance [1]

One of the most challenging aspects of esthetic dentistry is color assessment and its reproduction [2]. The aesthetics success of a ceramic restoration depends upon several factors such as substrate characteristics, shape, color, and integrity [3]. Shade matching of a ceramic restoration to the natural dentition represents a challenge for the clinician. To duplicate the color of a natural tooth, is required to determine clinically the shade, to communicate the shade to the dental laboratory technician and to reproduce the same shade in dental ceramics. Having no supporting metal substructure, ceramic restorations achieve light scattering and transmission that are like natural teeth [4,5].

The color of the substrate cannot always be chosen by the clinician, especially in the case of dyschromic abutments, cases in which the thickness of the ceramic restoration and the color of the chosen cement become important variables for manipulating the final color of the ceramic restorations. Moreover, the definitive color of a dental ceramic restoration depends on several factors such as spectral reflectance, thickness, translucency, and the underlying cement [6]

Previous studies have shown that an increase in the thickness of integral ceramics to 2mm or more is effective for masking the dyschromic substrate [7-9].

In many cases, obtaining a ceramic restoration with a 2 mm thickness can compromise the pulp of the dental abutment or can compromise the strength of the remaining dental structures. If a sufficient thickness of the restoration cannot be

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obtained, the color and thickness of the cement layer may be the only way of efficient masking of the substrate. The final color of a ceramic restoration depends on its degree of opacity, thickness and the color of the substrate and cement [10]. An opaque ceramic system has improved physical properties with the disadvantage of a less natural appearance due to the increased crystalline content [11]. A ceramic system with more translucent characteristics provides a better appearance because of the greater light transmission through the restoration [12]. The optical behavior of a ceramic restoration is determined by the combination of the tooth structure color, ceramic layer thickness and the cement color [13].

Traditionally, shade selection was performed visually with the aid of a shade guide [14]. The ability to perceive color differences varies from one person to another. Furthermore, the performance of shade matching may be affected by eye fatigue [15].

Shade matching technologies have been developed to increase the success of color matching, communication, reproduction, and verification in clinical dentistry and to increase the efficiency of esthetic restorative work [16].

Spectrophotometers can detect small differences in color that are not visible to the human eye. They became popular because of their accuracy, standardization and numerical expression of color and represent the most accurate instruments for color matching used in dentistry [17,18].

The numerical expression of color is expressed in CIE L*a*b* coordinates, which is a color system that is related to the color perception of the human eye. It is nearly a uniform color space with coordinates for lightness; white black (L*), red-green (a*), and yellow-blue (b*). Color change (ΔE) is a mathematical expression of the amount of difference between the L*a*b* coordinates of different specimens or the same specimen at different instances. (19). The dental literature states that the ΔE perceptibility threshold of 1, represents the 50:50 perceptibility threshold under controlled conditions, a ΔE of 2.7 and a ΔE of 3.3 were found to be the 50:50 acceptability threshold [20-22]. 50:50 perceptibility thresholds means that 50% of the observer will notice the color difference and 50% will not notice any difference and 50:50 acceptability threshold means that 50% of the observer will accept the restoration and 50% will replace it because of color mismatch [16].

II. MATERIAL AND METHODS

II.1. Specimen preparation

The monolithic materials tested in this study are listed in Table 1, along with their composition. 24 discs (n=12/subgroup) of nanoceramic resin (Cerasmart, GC Europe) and hybrid ceramic (Enamic, VITA, Zahnfabrik) were used.

Table 1. Classification, composition and manufacturer of the tested monolithic materials

Material	Classification	Composition	Manufacturer
Cerasmart	Nanoceramic resin	71% Silica and barium glass nanoparticles	GC Europe (Tokyo, Japan)
Enamic	hybrid ceramic with a dual network structure	SiO2 5–63%; Al2O3 20–23%; Na2O 6–11%;K2O 4–6%; B2O3 0.5–2%; CaO < 1%; TiO2 < 1%	VITA Zahnfabrik (Bad Säckingen, Germany)

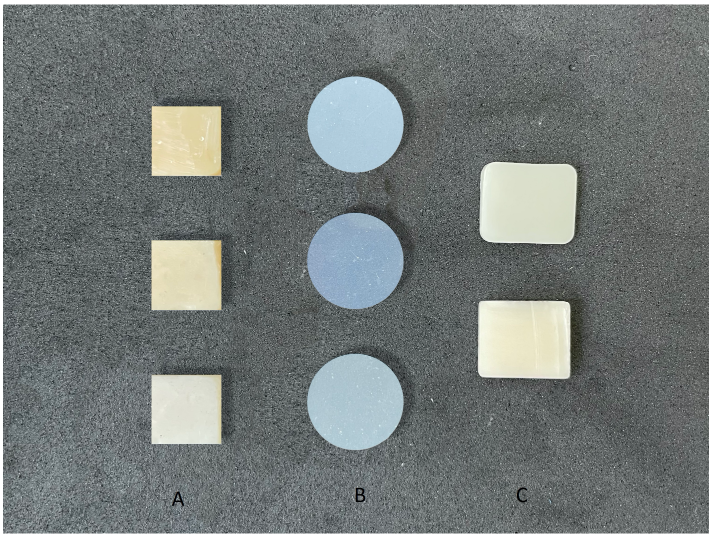

***Figure 1**. Test specimens. A, composite resin foundation specimens. B, cement shade specimens. C, ceramic discs specimens.*

CAD/CAM blocks were cut into discs of 1mm thick, with a precision saw (IsoMet 1000-Buehler, Lake Bluff, IL, USA) and a special disc used for cutting ceramics (IsoMet Diamond Wafering Blade, 15LC-Buehler, Lake Bluff, IL, USA) at a speed of 100 rotations per minute. The ceramic discs were finished with an abrasive paper (Klingspor, Haiger, Germany) using different granulations (P240-P1200).

The resin cement used in this study was Variolink Esthetic LC (Ivoclar, Vivadent, Liechtenstein, Germany, with three different shades (light, neutral and warm).

An amount of cement was placed and sandwiched between 2 pieces of transparent glass and light pressure was applied. The cement was then light polymerized using a light-emitting diode polymerization unit at 750 mW/cm^2 for 30 seconds on each side. Finally, the cement specimens were carefullly removed from between the glasses. A number of 3 cement specimens were prepared, one of each shade. All specimens were incubated (Cultura, Ivoclar, Vivaldent) for 24 hours at a temeprature of 37º C to ensure complete polymerization.

Three composite resin foundation specimens (14x12x4 mm) were fabricated in a silicone mold by using the A1, A3 and A3.5 shade of Evetric composite (Ivoclar, Vivadent, Liechtenstein, Germany) and then ground finished with a 600- to 1000-grit wet silicone carbide abrasive papers.

The speciment were superimposed in the following order: the composite resin foundation, the cement and the ceramic block.

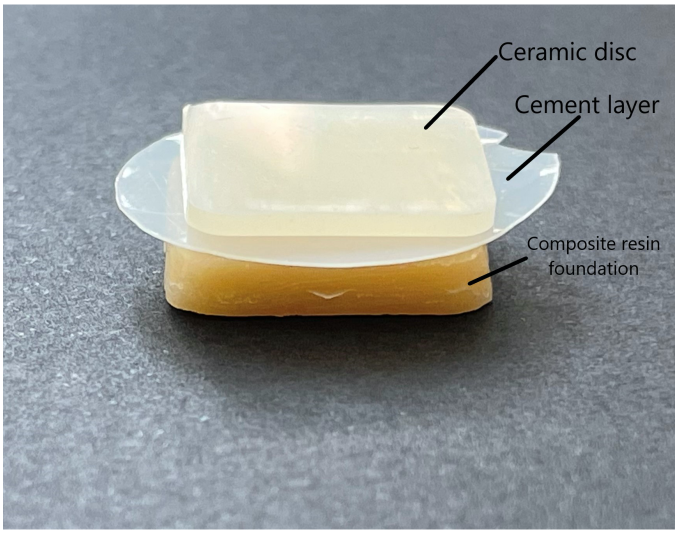

Figure 2. *Experimental design*

Color readings were conducted with a digital spectrophotometer (Vita Easyshade V, Vita Zahnfabrik). Before each reading, the device was calibrated with its calibration apparatus. The 6-mm-diameter measuring tip of the spectrophotometer was carefully placed at the center of the specimen to ensure complete contact between the tip of the device and the measuring surface.

The CIELab coordinated (L_1*, a_1*, b_1*) of 4-mm thick composite resin foundation with the ceramic disc superimposed served as the test group. The CIELab cordinates(L_2*, a_2*, b_2*) of ceramic discs on each combination of composite resin foundation and cement served as the test group. In all groups, 5 measurements were sequentially made and average values for L*, a*, b* coordinates were recorded. The color change was calculated for each sample with the following equation:

$$\Delta Eab = \sqrt{[(\Delta L^*)^2 + (\Delta_a^*)^2 + (\Delta b^*)^2]}$$

Where ΔL*, Δa*, Δb* represent the difference between the control and the test group.

A 3-way analysis of variance (ANOVA) was used to analyze the influence of 3 variables (the ceramic type, cement shade and composite resin foundation). The Tukey significant difference test was conducted whenever a statistically difference was found.

III. RESULTS AND DISCUSSION

Table 2 presents the mean ΔE value and standard deviations of the tested material combinations.

Three-way Anova indicated that ΔE values of specimens were influenced by composite resin foundation (CRF) and cement shade. The lowest and the highest mean ΔE values were found for Enamic-A1-Warm (0.115±0.041) and Cerasmart-A1-Light (2.066±0.029).

In case of strict overlapping of the ceramic discs over the composite substrate, it is observed that the substrate influences the final color of the ceramic.

For Enamic, the value closest to the control group (0.4825±0.09, $p < 0{,}001$), are obtained when using a substrate with shade A3.5 (0.653±0.056, $p < 0{,}001$), unlike Cerasmart where the value closest to the control group (0.465±0.071, $p < 0{,}01$) is obtained when using a substrate with shade A1 (0.434±0.037, p=0.2).

For Enamic, the comparison of different composite CRF shades in the same cement subgroups showed that A3 CRF with Neutral cement shade (ΔE =0.317±0.024; $p < 0{,}001$) showed the largest difference of ΔE values when compared to the ceramic disc superimposed on the CRF (ΔE =1.016±0.081; $p < 0{,}001$), in contrast to the A1 and A3.5 CRF with Neutral cement shade which showed a slight modification of ΔE values.

According to the spectrophotometric measurements, in the case of Enamic ceramic discs, which represent the control group (ΔE=0.4825±0.09, $p < 0.001$), the closest values to the control group are obtained with the A3.5 CRF and Warm shade of cement (ΔE=0.428±0.026, $p < 0{,}001$).

In case of Cerasmart ceramic discs, the closest value to the control group (ΔE=0.465±0.071, $p < 0.001$) is obtained with A3.5 CRF and Neutral shade of cement (ΔE=0.433±0.037, $p < 0.001$)

For Cerasmart, ΔE values shows that this type of ceramic undergoes color changes depending on the substrate and cement used, more than Enamic.

The biggest color changes occurred when composite resin foundation A1 and A3 were used in combination with Light cement shade, where ΔE values are 2.066±0.029 ($p < 0.001$) respectively 1.04±0.018 ($p < 0.001$); statistical analysis showing a very high significant result.

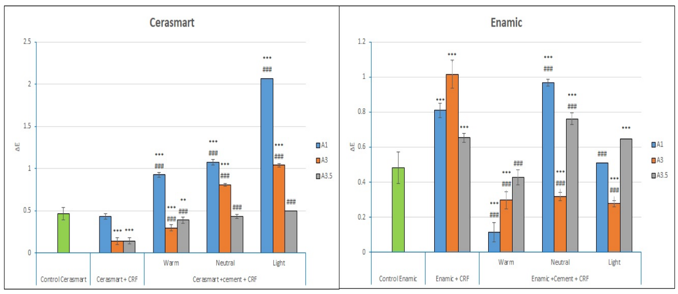

Fig 3. Mean color difference (ΔE) values with confidence intervals for Cerasmart and Enamic

Tabel 2. Mean ΔE and standard deviation

Resin-Matrix Ceramic Type	Composite Resin Foundation Shade	Cement Shade	Average & Standard Deviation
Enamic Control	-	-	0.4825±0.09
Enamic	A1	-	0.81±0.041
		Warm	0.115±0.041
		Neutral	0.96±0.054
		Light	0.51±0.019
	A3	-	1.016±0.081
		Warm	0.296±0.05
		Neutral	0.317±0.024
		Light	0.277±0.017
	A3.5	-	0.653±0.056
		Warm	0.428±0.026
		Neutral	0.761±0.043
		Light	0.648±0.034
Cerasmart Control	-	-	0.465±0.071
Cerasmart	A1	-	0.434±0.037
		Warm	0.925±0.035
		Neutral	1.075±0.028
		Light	2.066±0.029
	A3	-	0.141±0.039
		Warm	0.298±0.037
		Neutral	0.805±0.016
		Light	1.04±0.018
	A3.5	-	0.144±0.035
		Warm	0.389±0.038
		Neutral	0.433±0.037
		Light	0.5±0.02

This study evaluated the color change of CAD/CAM hybrid ceramic depending on the underlying substrate and the cement shade. To avoid error, color examinations should be performed with measurement devices [23].

Special instruments for clinical shade matching include colorimeters, imaging system and spectrophotometers [16]. In dentistry, the most accurate instruments for color matching of the restoration with natural teeth are considered to be spectrophotometers, because of their usefullness and aplicability [17]. Therefore, in the present study a spectrophotometer was used to measure color parameters (Vita Easyshade V, Vita Zahnfabrik).

Cement type exerts considerable influence on crown retention. Among the multitude of cement types existing on the market, adhesive cements have proven to give better results when used with full ceramic restorations.

The color and the optical properties of composite resin materials are determined by the resin matrix, filler composition, supplemental additives that include pigments and photo inhibitor [11,24]. The question arises about the effects of the cement on the final color of the restoration. Therefore, 3 cement shades (warm, neutral, light) were used for comparison in terms of color-changing effects. In this study, changing the underlying color of the composite resin foundation resulted modification of color parameters, but none of the results exceeded the perceptibility or the acceptability threshold. The present study determined that the use of a neutral cement shade with Enamic ceramic discs led to the highest delta E values, in comparison with other cement shades. Regarding Cerasmart ceramic discs, the use of a light cement shade led to the highest delta E values.

The main cited reasons for replacing anterior composite restorations and ceramic veneers are the esthetic issues [25]. Enamic and Cerasmart are both relative new materials, not sufficiently studied, therefore there is little evidence from clinical trials [26].

The limitation of this study include the fact that ceramic opacity is increased with the thickness [27]. As the thickness of ceramic increases, the majority of diffused reflection occurs in the restauration. This study did not compare the thickness parameters of the ceramic material. The influence of ceramic thickness, as well as optical properties such as translucency, chroma and hue should be evaluated in future in vitro and in vivo studies.

IV. CONCLUSION

Whitin the limitations of this study, the following conclusions can be drawn:

1. The underlying composite resin foundation and cement shade influence the resulting optical color of ceramic.
2. Changing the underlying composite color resulted in a minor modification of color parameters.
3. The three different color resin cement utilised in this study, lead to imperceptible ΔE coordinates

modifications, both for hybrid ceramic and nanoceramic discs.

Conflict of interest. None to declare.

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