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Masking Ability of the Combined Application of Opaquers and Resin Composite on Discolored Backgrounds

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Clinical Relevance

The combined application of opaquer and resin composite provides effective masking of mildly and intermediately discolored backgrounds, and contributes to less tooth reduction, thus preserving dental tissues. Alternative combinations should be applied to mask severely discolored backgrounds.

SUMMARY

The aim of this study was to evaluate the masking ability of a combined application of opaquers and resin composite over discolored backgrounds: A3, A3.5, C2, C3, and C4.

The groups were divided according to the opaquer brand, the number of opaquer coats (one or two), and the thickness of the resin composite layer (0.5 or 1.0 mm). The color measurements were made by a reflectance spectrophotometer (SP60, EX-Rite). The color difference between the opaquer + resin composite + background and a reference background was calculated using the CIEDE2000 formula. ANOVA and Tukey's *post hoc* test (α=0.05) were used to analyze the ΔE_{00} mean values. A bivariate analysis was used to determine the association between dependent and independent variables. The masking

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ability was rated by the ΔE_{00} visual thresholds of acceptability and perceptibility (Excellent Match: $\Delta E_{00} \leq 0.8$; Acceptable Match: $0.8 < \Delta E_{00} \leq 1.8$; Moderately Unacceptable Mismatch: $1.8 < \Delta E_{00} \leq 3.6$; Clearly Unacceptable Mismatch: $3.6 < \Delta E_{00} \leq 5.4$; Extremely Unacceptable Mismatch: $\Delta E_{00} > 5.4$).

The mean ΔE_{00} values ranged from 0.5 to 5.52. Masking ability was affected by the opaquer brand, thickness of the resin composite layer, and background shades. Most of the combinations that achieved either excellent or acceptable masking ability were obtained with combinations composed of one or two coats of opaquer and a 1.0-mm-thick resin composite layer for all backgrounds except C4. Acceptable results were also obtained for combinations with 0.5-mm-thick resin composite over C2, A3, and A3.5 backgrounds.

INTRODUCTION

Tooth discoloration in the anterior zone is a challenging clinical situation, especially when a single element is affected.[1] The proximity and contrast of this element with the adjacent teeth lead to a significant color mismatch.[2] Dental bleaching is a conservative technique that requires minimal intervention; therefore, it should be the first treatment choice for discoloration.[3] However, in some cases, discoloration is unresponsive to dental bleaching, or the esthetic outcome is not what is ideally expected.[3]

The resin composite layering technique is considered an option for masking discolored backgrounds. The combination of different shades and translucencies may give the final restoration a natural aspect, and also prevent transmission of the underlying dark color of the tooth surface or cavity floor.[4,5] However, direct resin composites have inherent limitations regarding opacification ability.[6] Depending on the severity of the discoloration, an opaque-shade resin composite layer that is at least 1.0-mm thick is needed to mask the underlying tooth structure.[7] Taking this into account, cavity preparation with tissue reduction is often required to provide thicker resin composite layers. Despite the variety of available approaches, masking is often not achieved without aggressive tooth preparation.[8-10]

Less invasive treatments performed in line with the minimal intervention approach should be preferred in the case of chromatic challenges.[1] Opaquers are fluid resins with high opacity agents, developed to be used in association with restorative materials to facilitate the masking of underlying structures[11, 12] and promote less tissue reduction.[7] Case reports show positive results for the combined applications of opaquers and resin composites.[10,12,13] However, the technical variations, application possibilities, and masking effectiveness of different degrees of discoloration have not yet been completely elucidated. A wide range of opaquers is commercially available. The ideal situation would be to have shades matching all of the resin composite systems. However, most of the commercial brands provide only one or two shade options, generally white opaque or universal opaque.[14] Therefore, it is important to investigate the masking ability of opaquers with different characteristics, shades, and opacification abilities, and determine the minimum thickness that will mask the discolored backgrounds.

The investigation of the processes involved in the masking ability of the combined application of opaquers and resin composites could improve esthetic outcomes and contribute to preserving dental structures by providing conservative dental preparations. Therefore, the purpose of this study was to evaluate the masking ability of different opaquer + resin composite combinations over simulated discolored backgrounds. The tested hypotheses consider that the masking ability of the combined application of opaquers and resin composites would be affected by the color of the backgrounds, by the brand of the opaquers, by the number of coatings of the opaquers, and by the resin composite thickness.

METHODS AND MATERIALS

Experimental Design

This laboratory study evaluated the masking ability of opaquers and resin composites placed over simulated dental backgrounds of different degrees of discoloration. The brand, composition, shade, and batch number of each material are presented in Table 1. The groups were divided according to the commercial brand of the opaquers, number of coatings of the opaquers (one or two coats), and thickness of the resin composite layer (0.5 or 1 mm). The experimental design and group divisions are presented in Figure 1.

Sample Preparation

Opaquer Coatings—A pilot study was conducted to determine the thickness of the opaquer coats. A thin layer of each opaquer was applied to a polyester sheet with a brush. After the opaquer was light-cured, the thickness of the opaquer + polyester sheet was measured with a digital caliper (Mitutoyo ABSOLUTE 500-196-20 Digital Caliper, Takatsu-ku, Kawasaki, Kanagawa,

Table 1: *Materials, Manufacturers, Composition, Shade, and Batch Number*				
Opaquer	**Manufacturer**	**Composition**	**Shade**	**Batch Number**
Empress Direct Opaque	Ivoclar Vivadent, Schaan, Liechtenstein	Dimethacrylates, barium glass, ytterbium trifluoride, Ba-Al fluorosilicate glass and mixed spheroidal oxides, catalysts, stabilizers, and pigments	Opaque	X16379
Opak	Angelus, Londrina, PR, Brazil	Bisphenol A diglycidyl methacrylate, urethane dimethacrylate, catalysts, stabilizers, pigments	A3	50458
Natural Flow Opaque	Nova DFL, Rio de Janeiro, RJ, Brazil	Bisphenol A diglycidyl methacrylate, dimethacrylate resins, boron-aluminum glass silicate, synthetic silica and pigments.	Opaque	18080524
Creative Color Opaquer	Cosmedent, Chicago, IL, USA	7,7,9-trimethyl-4,13-dioxo-3,14-dioxa-5,12-diaza-hexadecan-1,16-diol dimethacrylate, bisphenol a diglycidyl methacrylate; 1,4 butanediol dimethacrylate	A3	184218
Resin Composite	**Manufacturer**	**Composition**	**Shade**	**Batch Number**
Z350 XT	3M ESPE, St Paul, MN, USA	Bisphenol A diglycidyl methacrylate, urethane dimethacrylate, triethylene glycol dimethacrylate, bisphenol hydoxyethyl methacrylate, polyethylene gycol dimethacrylate, BHT, silicate, zircônia	A1B	1911600460

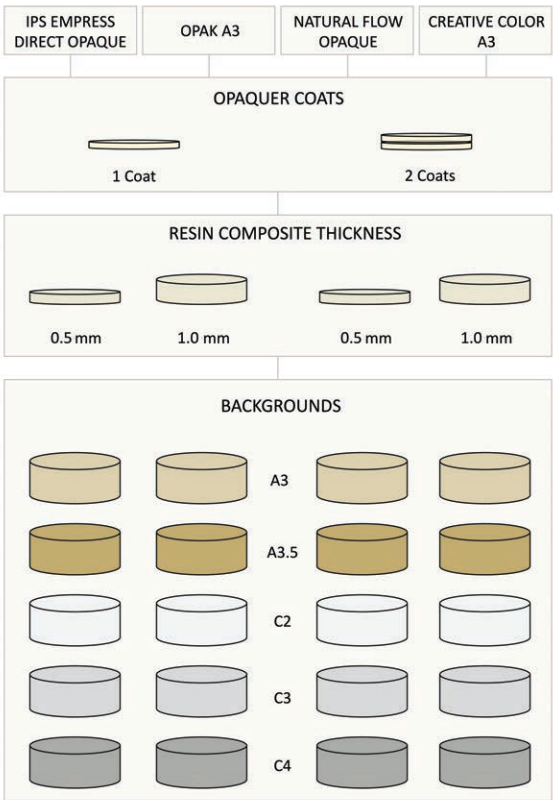

Figure 1. *Schematic representation of the experimental design and group division.*

Japan) and subtracted from the thickness of the polyester sheet. The same process was repeated in determining the thickness of two coats of each opaquer. All opaquer brands were measured five times for each option (one or two coatings), in triplicate, by the same operator, using a standardized procedure. The mean thickness values were used to determine the thickness of the opaquer coatings used in the present study.

One trained operator produced the samples. One drop of the opaquer was dispensed and pressed between two glass plates. Two polyester strips were placed between the opaquer and the glass plates for isolation purposes, and to prevent fracture of the sample after polymerization. A 0.75-kgf load was applied for 2 minutes to achieve disc films standardized at 30-μm thick and 11 mm in diameter. The upper and lower surfaces were light-cured for 40 seconds with a light-emitting diode (LED; Bluephase, Ivoclar Vivadent, Schaan, Liechtenstein) having 1000 mW/cm^2 irradiance.[15] The two-coat samples were obtained by pairing two opaquer coats using glycerin as a coupling medium between each coat.

Resin Composite Layers—The resin composite samples were made with an 11.0-mm diameter and 0.5-mm- or 1.0-mm-thick cylindrical metallic device. The resin composite was placed in one increment and light-cured for 40 seconds, on both sides, using an LED (Bluephase, Ivoclar Vivadent, Schaan, Liechtenstein) having 1000

mW/cm² irradiance. Prior to polymerization, the upper surface of the samples was covered with a polyester strip and a glass plate with 1 kgf static load.[7]

Discolored Backgrounds and Reference Background—Opaque shade ceramic discs, 11.0 mm in diameter and 2.0-mm thick,[7,16,17] were used to simulate discolored dental backgrounds. The backgrounds were fabricated from feldspathic porcelain, dentin opacity, and VM13—shades A3, A3.5, C2, C3, and C4 (Vita Zahnfabrik, Bad Säckingen, Germany).

An A1 body-shade resin composite (Filtek Z350XT, 3M ESPE, St. Paul, MN, USA) disc, 11.0 mm in diameter and 4.0-mm thick,[9] was used as a reference to calculate the color difference for every combination tested. This resin composite disc was produced with the same resin composite shade used previously, simulating a tooth with no discoloration and representing the color objective to be achieved by the masking techniques.

Color Measurement—The color of the samples was measured using a calibrated reflection spectrophotometer (SP60 - EX Rite, Grand Rapids, MI, USA) over a white background. The resin composite layer (0.5-mm or 1.0-mm thick) and opaquer coatings (one or two coats) were combined to simulate various restorative masking options. All measurements were performed using glycerin as a coupling medium between all layers, and between the samples and the simulated backgrounds.

The total color differences were calculated using the L*, a*, and b* values of the resin composite specimens placed over each colored background (A3, A3.5, C2, C3, and C4), and the L*, a*, and b* values of the A1 body shade resin composite, using the CIEDE2000 color difference formula:

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

where $\Delta L'$, $\Delta C'$, and $\Delta H'$ refer to lightness, chroma, and hue differences among the color measurements, respectively, and k_L, k_C, and k_H are the parametric factors for the influence made by the conditions and the illumination. R_T (rotation function) accounts for the interaction of hue and chroma differences in the blue region. S_L, S_C, and S_H are the weighting functions for the color difference adjustment, considering the location variation of L*, a*, and b* coordinates.[7,18] Metric discontinuities due to mean hue computation and hue-difference computation were taken into account to calculate the ΔE_{00}.[19]

The interpretation of masking ability effectiveness was based on visual thresholds of acceptability and perceptibility, and on ratings described by Paravina and others.[20] The ΔE_{00} threshold values and interpretation ratings are presented in Table 2. The color shifts resulting from applying different opaquers and resin composite combinations were analyzed by the differences in CIEDE2000 lightness, chroma, and hue values.[21] The CIEDE2000 lightness (ΔL_{00}), chroma (ΔC_{00}), and hue (ΔH_{00}) color differences were defined as[22]

$$\Delta L_{00} = \frac{\Delta L'}{k_L S_L}; \Delta C_{00} = \frac{\Delta C'}{k_C S_C}; \Delta H_{00} = \frac{\Delta H'}{k_H S_H}.$$

Statistical Analyses

The mean ΔE_{00} values were assessed by analysis of variance (one-way ANOVA) and Tukey's *post hoc* test (α=0.05). A bivariate analysis was used to determine the association between the dependent (masking ability) and independent variables (opaquer manufacturer, opaquer coat, resin layer, and background shades), using the chi-square test followed by the residual adjustment test. The significance level adopted was 5% (α=0.05). Statistical analysis was performed using an SPSS software program (SPSS Statistics 23.0.0, IBM Armonk, Chicago, IL, USA).

RESULTS

The one-way analysis of variance showed significant differences among the groups (p<0.001) for all background shades. Table 3 presents the mean and standard deviation values of ΔE_{00} for each opaque + resin composite combination and background (A3, A3.5, C2, C3, C4). The lower ΔE_{00} values are associated with increased masking ability. The combinations with a 1.0-mm-thick resin composite layer presented lower mean ΔE_{00} values, regardless of the commercial brand or number of coatings of the opaquers. This pattern was observed for the majority of the backgrounds.

Table 2. *Interpretation of Color Differences Between Different Dental Materials and Structures Through 50%:50% Perceptibility (PT) and Acceptability Thresholds (AT)*[20]

Threshold	Rating and Interpretation[a]	ΔE_{00}
≤PT	(5) Excellent match	≤0.8
>PT, ≤AT	(4) Acceptable match	>0.8, ≤1.8
>AT, ≤AT x 2	(3) Mismatch type [a]	>1.8, ≤3.6
>AT x 2, ≤AT x 3	(2) Mismatch type [b]	>3.6, ≤5.4
>AT x 3	(1) Mismatch type [c]	>5.4

[a] *Mismatch types: [a], moderately unacceptable; [b], clearly unacceptable; [c], extremely unacceptable.*

Table 3. *Mean and Standard Deviation Values of ΔE_{00} for Each Tested Combination and Background*[a]

Background		A3	A3.5	C2	C3	C4
Opaquers	**Combination**					
E	a	2.57 (0.13) bFG	2.56 (0.30) bGH	1.79 (0.45) aCDEF	2.11 (0.29) abB	4.16 (0.14) cD
	b	1.36 (0.48) aABCD	1.48 (0.56) aCDE	0.94 (0.54) aABC	1.28 (0.63) aA	2.45 (0.23) bAB
	c	2.64 (0.13) abG	2.77 (0.13) bH	2.18 (0.53) aF	2.48 (0.06) abBC	3.77 (0.15) cD
	d	1.77 (0.25) bBCDE	1.96 (0.33) bDEFG	1.72 (0.45) bBCDEF	1.01 (0.31) aA	2.14 (0.37) bA
O	a	1.97 (0.09) abDEFG	1.85 (0.20) aDEF	2.11 (0.07) bF	3.05 (0.07) cC	5.52 (0.05) dF
	b	1.15 (0.24) bcABC	0.65 (0.06) aA	1.01 (0.15) bABCD	1.41 (0.16) cA	3.15 (0.11) dC
	c	1.96 (0.08) aDEFG	2.02 (0.23) aEFG	2.37 (0.20) bF	2.69 (0.06) cBC	4.09 (0.19) dD
	d	0.81 (0.10) aA	0.82 (0.15) aAB	1.18 (0.09) bABCDE	1.23 (0.20) bA	2.16 (0.10) cA
N	a	2.19 (0.50) aEFG	2.06 (0.20) aEFG	1.95 (0.67) aEF	2.54 (0.22) aBC	4.79 (0.29) bE
	b	1.02 (0.44) abAB	1.01 (0.26) abABC	0.50 (0.40) aA	1.31 (0.55) bA	2.72 (0.14) cB
	c	2.44 (0.22) bEFG	2.32 (0.16) abFGH	1.99 (0.31) aEF	2.44 (0.26) bBC	4.58 (0.14) cE
	d	1.23 (0.62) aABCD	1.37 (0.43) aBCD	0.99 (0.44) aABC	1.32 (0.50) aA	2.72 (0.30) bB
C	a	1.83 (0.34) bCDEF	1.37 (0.30) aBCD	2.14 (0.23) bcF	2.48 (0.14) cBC	4.73 (0.05) dE
	b	0.68 (0.30) aA	0.63 (0.20) aA	0.90 (0.40) abAB	1.23 (0.13) bA	2.86 (0.10) cBC
	c	1.66 (0.47) aBCDE	1.81 (0.18) aDEF	1.87 (0.13) abDEF	2.32 (0.17) bB	4.15 (0.13) cD
	d	0.70 (0.44) aA	0.74 (0.20) aA	0.88 (0.46) aAB	1.25 (0.23) aA	2.45 (0.10) bAB

Abbreviations: E, Empress Direct Opaquer; O, Opak; N, Natural Flow; C, Creative Color; a, one opaquer coat + 0.5-mm resin composite layer; b, one opaquer coat + 1.0-mm resin composite layer; c, two opaquer coats + 0.5-mm resin composite layer; d, two opaquer coats + 1.0-mm resin composite layer.

[a] *Different lowercase letters in the same line indicate statistically significant differences. Different uppercase letters in the same column indicate statistically significant differences. Standard deviation values inside the parentheses.*

In an overall analysis, the comparison between the different colored backgrounds showed significantly higher mean ΔE_{00} values for C4 background, for all multilayering combinations. The comparison between multilayering combinations showed significantly lower mean ΔE_{00} values for the combinations with 1 or 2 opaquer coats combined with 1.0-mm resin composite (Table 3).

The association values (%) between dependent and independent variables are shown in Table 4. There was

a significant association between masking ability and opaquer brand (χ^2=9.92; p=0.019), and between resin composite layer (χ^2=134.02; p<0.001) and background shade (χ^2=78.80; p<0.001). The Creative Color Opaquer (Cosmedent) was significantly associated with acceptable masking ability, whereas Empress Direct Opaque (Ivoclar Vivadent) was significantly associated with unacceptable masking. A 1.0-mm resin composite layer was significantly associated with acceptable masking ability, and a 0.5-mm resin composite layer was significantly associated with unacceptable masking ability. Background shades A3, A3.5, and C2 were significantly associated with acceptable masking capacity, whereas C4 was associated with unacceptable masking ability.

Figure 2 presents the mean ΔE_{00} values for each group and the respective visual thresholds of perceptibility and acceptability.[20] Excellent matches ($\Delta E_{00} \leq 0.8$) were observed for combinations of one or two opaquer coats + a 1.0-mm resin composite layer associated with A3, A3.5, and C2 backgrounds. The acceptable matches for the C3 background were 1.0-mm resin composite layer combinations, regardless of the number of coatings. Acceptable matches were obtained for combinations with 0.5-mm-thick resin composite over C2, A3, and A3.5 backgrounds. The majority of opaquer + resin composite combinations associated with the C4 background presented clearly unacceptable mismatch threshold values, and no masking ability was detected.

Figure 3 shows the ΔL_{00}, ΔE_{00}, and ΔH_{00} shifts for clearly unacceptable opaque + resin composite combinations over the C4 background. The ΔE_{00} color shifts were mostly influenced by ΔC_{00} for combinations associated with the A3, C2, C3, and C4 backgrounds. Overall, the combinations were just slightly affected by ΔH_{00} and ΔL_{00}, except for Opak combinations associated with the A3 and A3.5 backgrounds, and Empress combinations associated with the A3, A3.5, and C2 backgrounds, respectively.

DISCUSSION

The present study evaluated the masking ability of the combined application of four opaquers—in one or two coats—and one resin composite in two thicknesses—0.5 mm and 1.0 mm—over different background shades. The combined application of opaquer and resin composite

Table 4. *Association Values (%) Between Masking Ability and Opaquer Manufacturer, Opaquer Coats, Resin Composite Layer Thickness, and Background Shades*

	Masking Ability[a]		
Opaquers + Resin Composite	**Acceptable - ΔE_{00}≤1.8 n (%)**	**Unacceptable - ΔE_{00}>1.8 n (%)**	***p*-value**
Opaquers			
Creative Color	**56 (31.6%)**	44 (19.7%)	0.019
Empress	34 (19.2%)	**66 (29.6%)**	
Natural Flow	43 (24.3%)	57 (25.6%)	
Opaque	44 (24.9%)	56 (25.1%)	
Opaquer Coats			
1	93 (52.5%)	107 (48.0%)	0.365
2	84 (47.5%)	116 (52.0%)	
Resin Composite Thickness			
0.5 mm	31(17.5%)	**169 (75.8%)**	<0.001
1.0 mm	**146 (82.5%)**	54 (24.2%)	
Background Shades			
A3	**45 (25.4%)**	35 (15.7%)	<0.001
A3.5	**45 (25.4%)**	35 (15.7%)	
C2	**49 (27.7%)**	31 (13.9%)	
C3	37 (20.9%)	43 (19.3%)	
C4	1 (0.6%)	**79 (35.4%)**	

[a]*Percentual values (%) are in the parentheses. Absolute residuals in bold are those that exceed +/- 2.*

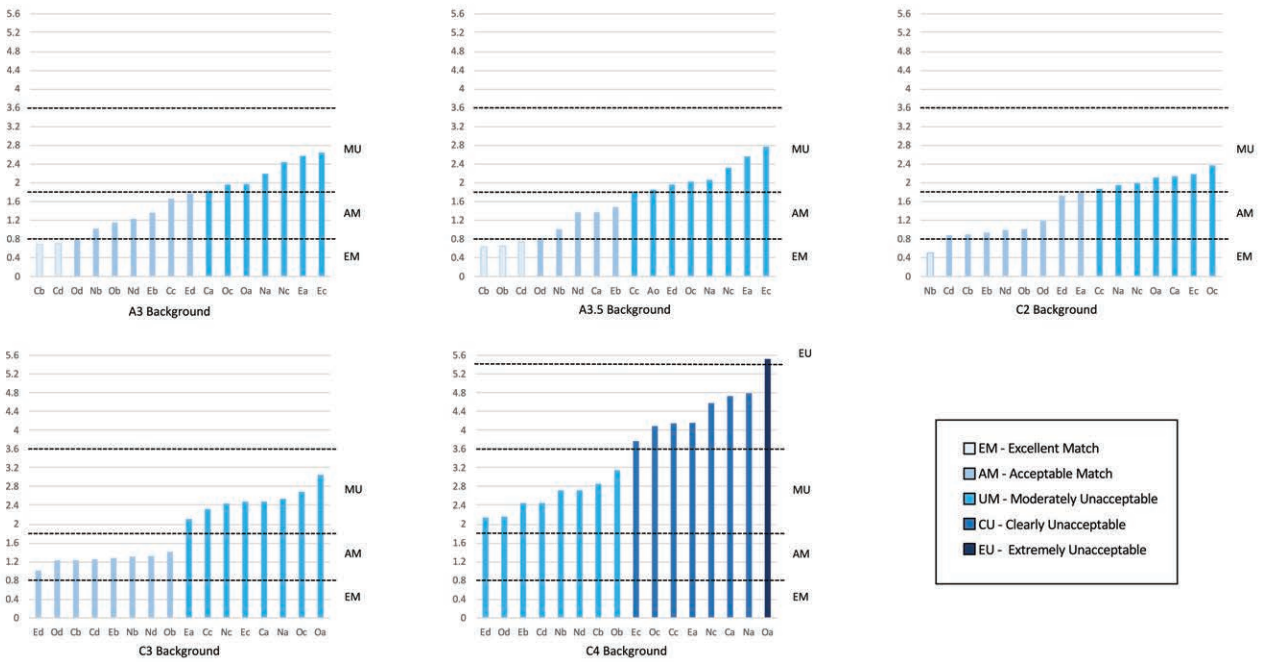

Figure 2. *Mean ΔE_{00} values for A3, A3.5, C2, C3, and C4 backgrounds and threshold interpretation ratings for each combination. Abbreviations: E, Empress Direct Opaquer; O, Opak; N, Natural Flow; C, Creative Color; a, one opaquer coat + 0.5-mm resin composite layer; b, one opaquer coat + 1.0 mm resin composite layer; c, two opaquer coats + 0.5-mm resin composite layer; d, two opaquer coats + 1.0-mm resin composite layer; EM, excellent match; AM, aceptable match; UM, moderately unacceptable mismatch; CU, clearly unacceptable mismatch; EU, extremely unacceptable mismatch.*

achieved effective masking ability over the majority of the backgrounds. The tested hypothesis was partially accepted because the masking ability was influenced by the opaquer brands, resin composite thickness, and background shades, whereas the number of opaquer coats did not significantly affect the masking ability.

According to the manufacturers' instructions, the opaquers should be applied with a fine brush in thin coats. Clinically, the opaquers are applied over the discolored background, with no set pattern.[23] Depending on the inherent characteristics of the opaquer, such as opacity/translucency, viscosity, color, and the relation between the severity of the discolored background versus the color objective to be achieved, an additional coating may be applied to increase the thickness of the opaquer layer, and to achieve greater

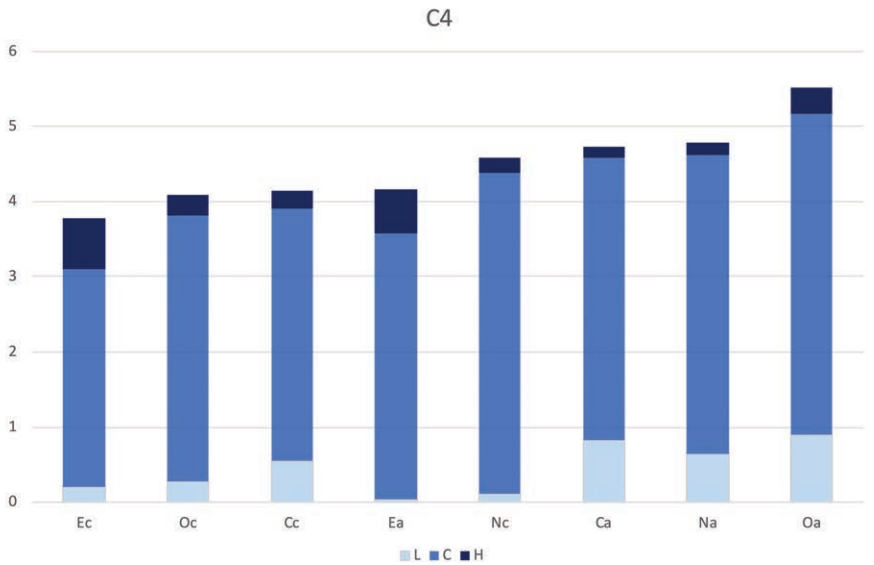

Figure 3. *CIEDE2000 (ΔE_{00}) color shifts for clearly unacceptable combinations associated with C4 discolored background. The influence of the lightness, chroma, and hue differences in the total color shifts is shown. Abbreviations: E, Empress Direct Opaquer; O, Opak; N, Natural Flow; C, Creative Color; a, one opaquer coat + 0.5-mm resin composite layer; c, two opaquer coats + 0.5-mm resin composite layer; L, ΔL_{00} CIEDE2000 lightness difference; C, ΔC_{00} CIEDE2000 chroma difference; H, ΔH_{00} CIEDE2000 hue difference.*

coverage of the background. The shade and the choice of the opaquer manufacturer may be selected by the operator, whereas the thickness cannot be completely controlled,[24] making it difficult to obtain the exact measurement of the coating thickness. The thickness of the opaquer coatings used in the present study was determined by a pilot study because the authors could not find any published data regarding the thickness of the opaquer coat to use as a reference.

Dental discolorations may be caused by different factors, such as pulp hemorrhage, pulp necrosis, pulp canal calcification, endodontic materials,[25] tetracycline-containing medicines, and exposure to food and beverage pigments and tobacco smoke.[26] Depending on the etiological factor that caused the color alteration, a wide variety of shade and discoloration intensities may be observed.[25,26] In the present study, five background shades were selected in order to simulate different conditions and degrees of masking difficulty found in clinical practice. The C2 background simulates a mild discoloration, A3 and A3.5 an intermediate discoloration, and C3 and C4 a severe discoloration, thus representing low, medium, and high masking difficulty.[27,28]

Resin composites have limited masking ability, owing to their inherent optical properties.[1] Their masking ability is affected by the translucency and thickness of the layers, as well as the degree of discoloration of the underlying tooth structures.[4,5,7-9,29-31] Darker backgrounds are more difficult to mask. In these situations, opaque shades and thicker resin composite layers are recommended to achieve improved masking ability.[4,7,16,32]

The concept of minimally invasive dentistry has driven esthetic treatments to adopt a more conservative approach, designed to preserve tooth structure.[33,34] However, conservative preparations imply a reduced thickness of the composite layer, hence a greater influence of the background on the final color of the restoration.[4,5,7,9,30,32] Opaquers may contribute to preserving dental structures because their high opacification ability allows them to be used in very thin coats.[1]

This study was undertaken to simulate esthetic treatment solutions in line with the minimally invasive concept, by testing the combined application of opaquers and resin composite layers with reduced thicknesses. The four opaquers tested are basically composed of highly pigmented resinous materials containing metal oxides that are responsible for their opacification, characteristic tint, and saturation.[1] The opaquers were selected among the commercially available brands. Opaquers with different characteristics within the commercial brands available were selected to represent a wide range of opacification possibilities. The shade selection was determined based on the options available for each product. Empress Direct Opaque (Ivoclar Vivadent) and Natural Flow Opaque (Nova DFL) have only one universal opaque shade option. Opak (Angelus) has two shade options (B0.5 and A3) and Creative Color (Cosmedent) has a wide variety of shades. Shade A3 was selected for both Opak (Angelus) and Creative Color (Cosmedent) to standardize the hue and chroma, because it was the only shade shared by the two products.

Color measurements were performed using glycerin as a coupling medium between the resin composite and the opaquer and the porcelain background, to enhance the optical contact between each layer of the specimens. Glycerin was used ultimately to simulate the oral environment[35] to prevent undesirable effects of air on optical properties[36] and to minimize the light refraction that occurs when a light beam crosses materials with different refractive indices.[37] It is recommended that the refractive index of the coupling agent and the tested materials be the same.[37,38] Glycerin, porcelain,[37] and resin composites[39-41] have similar refractive indices (n=1.5). However, it could be assumed that the opaquers would present a higher refractive index (n>1.5), owing to their higher opacity.[41] The possible difference in the refraction indices could be considered a limitation of the present study, and should be taken into account when interpreting the present results and applying them in clinical practice.

The effectiveness of the masking ability was visually interpreted according to the perceptibility and acceptability thresholds for ΔE_{00}.[20] In an overall analysis, an excellent match was achieved for a small number of combinations (8%). The feature that these combinations held in common was the thickness of the resin composite layer. The combinations that yielded excellent match were obtained with a 1.0-mm-thick layer of resin composite, regardless of the number of coatings of the opaquers. In the present study, the masking ability was negatively affected when the thickness of the resin composite layer was reduced to 0.5 mm. These findings are in line with previous research that has reported an improvement in masking ability when the thickness of the resin composite layer is increased.[4,5,7,8,16,29,30,32,42] Acceptable matches with a mean ΔE_{00} ranging from $0.8 > \Delta E_{00} \leq 1.8$ were also found, mainly for combinations of 1.0-mm-thick resin composite layers for all backgrounds except C4. Moderately unacceptable matches were observed in all backgrounds, and were generally associated with 0.5-mm resin composite layers. However, in some situations, acceptable results were observed for 0.5-mm-thick resin composites combined with both Creative Color

and Empress Direct opaquers over C2, A3, and A3.5 backgrounds. This confirms that opaquer coatings may improve the masking of discolored backgrounds with 1.0-mm and 0.5-mm-thick resin composite layers, and thus contribute to minimizing tooth reduction.

Previous studies showed effective masking with a 1.5-mm-thick dentin shade resin composite.[7,16] However, it is important to understand that additional space is required for resin composite layering to achieve a natural appearance in the final restoration.[43] The body shade resin composite used in the present study is considered a universal resin composite, with an intermediate translucency that is lower than the enamel shade and higher than the dentin shade.[9] The present study demonstrated that the combined application of opaquers with a less opaque universal resin composite may be achieved, thus reducing the space required for layering.

The tested backgrounds that simulated discolored tooth structures differed in regard to hue, chroma, and brightness. According to the VITA Lumin Classical Shade Guide manufacturer, the following sequence was observed when arranged in descending order of brightness (value): C2 > A3 > A3.5 > C3 > C4.[44] The C2 background was the most favorable color match, obtained from the combination of one coat of Natural Flow opaquer + 1.0-mm-thick resin composite layer, with a mean ΔE_{00} value of 0.5. In contrast, the C4 background had the highest chromatic discrepancy, obtained from the combination of one coat of Opak opaquer + 0.5-mm-thick resin composite layer, with a mean ΔE_{00} value of 5.52. These findings may be attributed to the brightness of the C2 and C4 backgrounds, since they represent the highest and the lowest brightness values, respectively, among the tested backgrounds.[44] Clearly unacceptable and extremely unacceptable mismatches were observed only for the C4 background, corroborating previous studies indicating that darker backgrounds with lower values are more difficult to mask.[4,5,7-9,16,30,32]

The relative visual ascending order of translucency among the tested opaquers considers Opak < Empress Direct Opaque < Creative Color ≤ Natural Flow (Figure 4). The most translucent opaquers were as effective as the least in masking most of the backgrounds. In contrast, not even the least translucent opaquers were able to achieve acceptable matching values for the C4 background.

The ability to mask different backgrounds is a complex mechanism that involves light absorption and scattering.[4] The metal oxides present in the composition of the opaquers increase the light that is reflected toward the observer, thus improving the ability to mask the color of the underlying background.[1,4] However, opaquers with high opacity do not always provide the best results. Excessive opacity may negatively affect the final color of the restoration, especially over mild discolorations and conservative preparations, leading to lifeless and unnatural results.[14] This is confirmed by the positive results achieved with both the Creative Color and the Empress Direct opaquers combined with a 0.5-mm-thick resin composite over C2, A3, and A3.5 backgrounds. Both opaquers tested presented effective masking with reduced thickness of the resin composite, but did not present the highest opacity visually.

The clinical significance of the results points out that not only do the opaquers differ in masking ability, but the masking ability is influenced by the background color and thickness of the composite layer. In general, the application of one or two opaquer coats combined with a 1.0-mm-thick layer of body shade resin composite is recommended for covering discolored backgrounds, and providing restorations with an acceptable match. However, in cases of mild and intermediate background discolorations (C2, A3, A3.5 shades), the application of one or two opaquer coats combined with a 0.5-mm-thick layer of body shade resin composite may also provide adequate masking of the background color. In order to mask darker substrates, alternative combinations with thicker layers of dentin shade resin composites should be applied.

The combined application of opaquer and resin composite is a less invasive option for masking discolored backgrounds. However, there are few studies that have addressed the combined effect of these materials.[10,13,45] The majority of the findings regarding the use of opaquers have been reported in the form of case reports; hence, this topic has not been thoroughly researched. The understanding of the optical behavior of each opaquer is essential to obtain the high-quality masking of discolored backgrounds. Future studies with different combinations of resin shades, stratification techniques, and thicker opaquer coatings are recommended to

Figure 4. *Photographic demonstration of the relative ascending order of translucency among the tested opaquers: Opak < Empress Direct Opaque < Creative Color ≤ Natural Flow.*

solve the difficulties regarding the masking of severely discolored backgrounds. To date, this study was able to clarify some important issues regarding the combined application of opaquers and resin composites, and also contribute to the understanding of the behavior of these materials of great, but underinvestigated, potential.

CONCLUSIONS

The masking ability of a combined application of opaquer and resin composite was affected by the opaquer brand, resin composite thickness, and background shade. Most of the results that achieved either excellent or acceptable masking ability were obtained with combinations composed of one or two coats of opaquer and a 1.0-mm-thick resin composite layer. Acceptable masking ability was obtained for combinations with 0.5-mm-thick resin composite over C2, A3, and A3.5 backgrounds, and with 1.0-mm-thick opaquer-resin combinations over all backgrounds except C4.

Conflict of Interest

The authors have no financial interest in any of the companies or products mentioned in this article.

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