©Operative Dentistry, 2022, **46-5**, 559-565

The Thickness and Opacity of Aesthetic Materials Influence the Restoration of Discolored Teeth

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Clinical Relevance

Composite resin and/or ceramic veneer restorations show similar masking ability on discolored teeth, with varied opacities and thickness combinations within clinically relevant conditions.

SUMMARY

Objectives: This study aimed to evaluate the influence of thickness and opacity on the ability of composite resin and ceramic veneer restorations to mask discolored teeth.

Methods: Ninety veneers were made of lithium disilicate ceramic, shades BL1 and 0 (IPS e.max Press, Ivoclar Vivadent), and 60 were made of composite resin, shade BL-L (IPS Empress Direct, Ivoclar Vivadent). The veneers measured 4 mm in width x 4 mm in length and had a thickness of 0.7, 1.0, or 1.2 mm. One hundred and fifty human premolars were selected to obtain 150 dental fragments with the following dimensions: 4 mm x 4 mm x 3 mm (width x length x thickness). The fragments were discolored, submitted to color measurement and randomly assigned to 15 groups (n=10) according to the type and opacity of the restorative material (IPS e.max Press: high translucency [HT], low translucency [LT], and medium opacity [MO]; IPS Empress Direct: dentin and enamel) and thickness of the veneers (0.7, 1.0, and 1.2 mm). After cementation of the ceramic or composite resin veneers using a translucent resin cement (RelyX veneer, 3M), a final color measurement was taken from each specimen and the total color variation (ΔE) was calculated by subtracting the initial and the final color measurement. The final lightness (L*) of the restored dental fragments was also calculated.

Results: The highest ΔE values were observed for the LT and MO ceramic groups, followed by dentin composite resin. Regarding the different thicknesses of ceramic veneers, every 1.2-mm–thick group had higher values of ΔE, considering their respective opacities (p<0.05). The highest lightness values were found for the LT and MO ceramic veneers (thickness of 1.2 mm). Dentin-shade composite resins showed similar lightness values in all groups.

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http://doi.org/10.2341/19-093-L

Conclusion: The best thickness/opacity combinations for masking discolored dental substrates were LT and MO ceramic veneers with 1.2-mm thickness. Dentin-shade composite resin veneers with a thickness of 0.7-1.0 mm showed good ability to mask discolored dental substrates.

INTRODUCTION

Chromatic changes in anterior teeth are frequent complaints of patients in clinical practice.[1] Depending on the etiology, discoloration may affect an individual tooth or a group of teeth, and treatment may range from bleaching of vital or non-vital teeth to more invasive procedures. When bleaching is not sufficient to change the chromatic characteristics of severely discolored teeth, dental practitioners can offer other procedures such as composite resin restorations, dental veneer restorations and all-ceramic crowns to their patients.[2-4]

In addition to the type of treatment, the characteristics of the chosen restorative material also influence its ability to mask a discolored tooth. Composite resin is a restorative material widely used for recovering an aesthetic smile. It is a versatile material whose optical characteristics permit harmonic reproduction of the tooth. Composite resins are also initially cost-effective, especially when compared to ceramics.[5] Although composite resins are widely used in clinical dental practice, studies evaluating their ability to mask discolored teeth are scarce. Another approach to vestibular surface restorations is the use of ceramic materials, such as laminate veneers. Ceramic materials are a restorative solution that balances functional and aesthetic needs of the anterior dentition with high durability and color stability.[6] However, when ceramic materials are used for masking discolored teeth, one or more of the following options may be taken into account: less translucent laminates, high-thickness restorative materials, and/or luting agents with high opacity.[7-11]

There is no consensus in the scientific literature regarding the required thickness of a restorative material to mask a discolored tooth.[12-15] Furthermore, few studies have compared the masking ability of composite resins and ceramic veneers on discolored teeth by varying thickness and opacity levels. Therefore, using the CIE L*a*b* system parameters (Commission Internationale de l'Eclairage), the present study aimed to evaluate the influence of the thickness and opacity of aesthetic restorative materials (composite resins and ceramic veneers) on restored discolored teeth.

METHODS AND MATERIALS

Layered pressed lithium disilicate ceramic was used as the ceramic system (IPS e.max Press, Ivoclar Vivadent, Schaan, Liechtenstein), BL1 shade for high translucency (HT) and low translucency (LT), and 0 shade for medium opacity (MO). The resin composite system consisted of IPS Empress Direct (Ivoclar Vivadent), BL-L shade with two levels of translucency (enamel and dentin shades). A list of the materials and their respective composition is depicted in Table 1.

One hundred and fifty laminates were prepared using the two restorative materials. The laminates measured 4 mm in width and 4 mm in length and had different thicknesses (0.7, 1, or 1.2 mm). The ceramic veneers had three different opacities (HT, LT, or MO), while the composite resin veneers had two different opacities (enamel or dentin shade), resulting in 90 ceramic and 60 composite resin restorations.

The ceramic specimens were obtained from previous wax mold samples, with a width x length of 4 mm x 4 mm and thickness of 0.7, 1, or 1.2 mm. After cooling

Table 1: *List of the Restorative Material Systems and Their Respective Composition*

Restorative Material	Composition[a]
IPS E.max Press (Ivoclar Vivadent)	Main component: SiO_2 Additional component: Li_2O, K_2O, MgO, ZnO, Al_2O_3, P_2O_5 and other oxides
IPS Empress Direct (Ivoclar Vivadent)	20-21.5% by weight of dimethacrylates 17% by weight of opalescent color 77.5-79% by weight of barium glass, ytterbium trifluoride, mixed oxides, silicon dioxide and copolymer <1% by weight of additives, catalysts, stabilizers, and pigments Inorganic particle size: 40 nm to 3000 nm (Ma = 550 nm)

Abbreviations: Al_2O_3, aluminum oxide; K_2O, potassium oxide; Li_2O, lithium oxide; P_2O_5, phosphorus pentoxide.
[a]*Manufacturers' information.*

the refractories, the laminates were removed and finished using cleaning and glazing procedures.

The composite resin was placed into perforated stainless-steel matrices with a metal spatula. A polyester strip and a weight of 500 g were applied to the matrices for 30 seconds in order to remove excess resinous material. Next, the specimens were light cured for 40 seconds using a LED-laser source (Valo, Ultradent Products, South Jordan, UT, USA). The light intensity was 1000 mW/cm^2.

The dental specimens were obtained by selecting premolars from the Human Teeth Bank of the União Metropolitana de Educação e Cultura – UNIME (Lauro de Freitas, Bahia, Brazil), which had been stored in 0.1% thymol solution. The crowns of the teeth were separated from the roots with a double-sided diamond disc (ref 7020, KG Sorensen, São Paulo, Brazil) at low temperature and low speed. After removing the pulp tissue, the dental crowns were washed and cleaned using Robinson brushes and pumice paste under running water at low rotation. One dental fragment, from the center of respective vestibular surfaces, was removed from each premolar, for a total of 150 dental fragments with the following dimensions: 4 mm x 4 mm x 3 mm (width x length x thickness). Thereafter, the fragments were stored in distilled water for 24 hours at 37°C.

The fragments were fixed onto an acrylic device with a sticky wax (ASFER, Indústria Química Ltda, São Paulo, Brazil) and placed into an AROPOL 2V metallographic polishing machine (AROTEC, Indústria e Comércio S/A, Cotia, Brazil). During the polishing sessions, aluminum oxide papers with a grain size of P1200 and P2000 were used for 20 seconds at a constant low temperature. The dental fragments were individually submitted to an ultrasonic bath (CBU-100/1L, PLANATC, São Paulo, Brazil) in distilled water for two minutes. Next, the fragments were soaked in an aqueous solution composed of 250 mL black tea, 250 mL coffee, 250 mL red wine, 250 mL tobacco solution, 250 mL Coca-Cola and 250 mL artificial saliva, and then placed in an incubator for 96 hours at 37°C.[16] Before the initial color assessment, the dental fragments were individually coded and randomly divided into 15 experimental groups of 10 specimens each (Table 2).

The ceramic and resin laminates were cemented to the discolored fragments using 37% phosphoric acid (Condac, FGM, Santa Catarina, Brazil), an adhesive system (Scotchbond Multipurpose Plus, 3M, St Paul, MN, USA), silane (Prosil, FGM, Santa Catarina, Brazil), and a translucent resin cement (RelyX veneer, 3M). After laminate cementation following manufacturer's instructions for each material, the specimens were submitted to the final color evaluation.

Each specimen was submitted to two color measurements: 1) after discoloration of the dental fragments before adhesive cementation of the veneers, and 2) after cementation of the ceramic or resinous laminates to the discolored dental fragments. Thus, each specimen was compared to itself between time points. This method reduced *in vitro* variability, permitting a more reliable analysis of the masking ability of the restorative materials used in each experimental group. In addition, the initial color measurement enabled determination of the color homogeneity of the fragments among the experimental groups by comparing their means and standard deviations.

The color measurements were performed using a spectrophotometer (UV-2600, Shimadzu, São Paulo, Brazil), and the UVProbe software was used to obtain the spectral reflectance curves of each specimen within the visible light spectrum of 380 to 780 nm. For this purpose, the specimens were placed onto a white standard background (barium sulphate) with the aid of a template to reproduce their position. The spectra of

Table 2: *Experimental Groups Divided According to the Thickness and Opacity of the Dental Materials*

	Opacity				
	Ceramic (IPS E.max Press) Shade: BL1 (HT and LT); 0 (MO)			**Resin (IPS Empress Direct) Shade: BL-L**	
Thickness	**HT**	**LT**	**MO**	**Enamel**	**Dentin**
0.7 mm	G1 (n=10)	G4 (n=10)	G7 (n=10)	G10 (n=10)	G13 (n=10)
1.0 mm	G2 (n=10)	G5 (n=10)	G8 (n=10)	G11 (n=10)	G14 (n=10)
1.2 mm	G3 (n=10)	G6 (n=10)	G9 (n=10)	G12 (n=10)	G15 (n=10)

Abbreviations: G1 to G15, experimental group 1 to experimental group 15; HT, high translucency; LT, low translucency; MO, medium opacity.

each specimen were analyzed using the Color Analysis software (Color Measurement Software, Shimadzu, São Paulo, Brazil), and color assessment was performed according to the parameters of the CIE L*a*b* system, with CIE illuminant D65 as reference illuminant.[17]

First, exploratory analysis of the lightness and ΔE values was performed to assess the data distribution (Shapiro-Wilk test; $p>0.05$) and other parameters of analysis of variance (ANOVA). For inferential statistical analysis, two-way ANOVA, followed by Tukey's post-hoc test, was applied for multiple comparisons between means. Data were analyzed using the SAS 9.1 software and are expressed as means and standard deviation (SD). Differences were considered statistically significant when $p\leq0.05$.

RESULTS

The results of exploratory analysis showed a normal distribution of the ΔE (color difference) values between groups. Table 3 depicts the ΔE values of each experimental group. Statistical analysis (two-way ANOVA followed by the Tukey post-hoc test) revealed a significant interaction between the factors studied (thickness versus opacity, $p<0.001$).

When thicknesses were 0.7 mm and 1.0 mm, different groups with different opacities showed similar variation. The highest ΔE values were observed for dentin resin veneers, followed by LT and MO ceramic veneers, which had the same ΔE values. In descending order, the lowest ΔE values were observed for enamel resin laminates and HT ceramic veneers.

Considering the groups with 1.2-mm thickness, the highest ΔE value was observed for LT ceramic veneers, although it did not differ significantly from the ΔE value of the MO ceramic group. In addition, statistical analysis revealed no difference in ΔE values between the MO ceramic and dentin resin groups. The ΔE values decreased in the enamel resin group, followed by the HT ceramic group. It is noteworthy that for the three different ceramic veneer opacities, significantly higher ΔE values were found for the 1.2-mm thickness groups compared to the groups with thicknesses of 0.7 and 1.0 mm under most conditions.

The ΔE values of the enamel resin groups (0.7, 1.0, and 1.2 mm) were significantly different from each other. Conversely, there was no significant difference between the dentin resin groups with 1.2 mm thickness and the 1.0 mm thickness group, and both groups exhibited higher ΔE values than the 0.7 mm thickness group.

Table 4 depicts the lightness variation in each experimental group. Statistical analysis (two-way ANOVA followed by the Tukey post-hoc test) showed a significant interaction ($p<0.001$) and a statistical relationship between the factors studied.

Comparing the experimental groups with 0.7 mm thickness, the highest lightness values were found for MO ceramic veneers and dentin resin veneers, with no significant difference between groups. Both groups differed significantly from the other 0.7 mm thickness groups. There was no significant difference in lightness levels between the HT, LT, and enamel resin groups.

In the groups with 1.0 mm thickness, statistical analysis showed similar lightness levels for the LT and MO ceramic veneer and dentin resin groups. These groups differed significantly from the remaining groups, and showed higher lightness levels than the enamel composite resin and HT ceramic groups.

At a thickness of 1.2 mm, there was no significant difference between the LT and MO ceramic groups;

Table 3: *Color Variation (ΔE) of the Experimental Groups Expressed as Means and Standard Deviation (SD)*[a]

	Thickness		
Opacity	**0.7 mm**	**1.0 mm**	**1.2 mm**
Ceramic (HT)	2.59 (0.20) Db	2.80 (0.27) Db	3.32 (0.25) Da
Ceramic (LT)	4.21 (0.14) Bb	4.49 (0.42) Bb	5.71 (0.21) Aa
Ceramic (MO)	4.28 (0.18) Bb	4.46 (0.23) Bb	5.48 (0.30) ABa
Resin (Enamel)	3.24 (0.15) Cc	3.93 (0.39) Cb	4.54 (0.52) Ca
Resin (Dentin)	4.78 (0.47) Ab	5.24 (0.17) Aa	5.22 (0.07) Ba

Abbreviations: ANOVA, analysis of variance; HT, high translucency; LT, low translucency; MO, medium opacity.

[a]*Means (SD) followed by distinct letters represent statistical significance (two-way ANOVA followed by Tukey post-hoc test; alpha level of 5%). Uppercase letters compare different levels of opacity within a settled thickness (comparison of cells in a same column). Lowercase letters compare different levels of thickness within a settled opacity (comparison of cells in a same line).*

Table 4: *Luminosity of the Experimental Groups, Expressed as Means and Standard Deviation (SD)*[a]

	Thickness		
Opacity	**0.7 mm**	**1.0 mm**	**1.2 mm**
Ceramic (HT)	71.60 (0.83) Cb	70.92 (0.65) Cb	72.89 (0.86) Ca
Ceramic (LT)	77.53 (0.73) Bc	79.90 (0.62) Ab	83.07 (0.95) Aa
Ceramic (MO)	79.16 (0.69) Ac	80.82 (0.93) Ab	83.37 (1.01) Aa
Resin (Enamel)	72.88 (0.67) Cb	73.95 (0.30) Bb	79.47 (0.61) Ba
Resin (Dentin)	80.12 (0.70) Aa	79.77 (0.44) Aa	80.13 (0.81) Ba

Abbreviations: ANOVA, analysis of variance; HT, high translucency; LT, low translucency; MO, medium opacity.

[a]*Means (SD) followed by distinct letters represent statistical significance (two-way ANOVA followed by Tukey post-hoc test; alpha level of 5%). Uppercase letters compare different levels of opacity within a settled thickness (comparison of cells in the same column). Lowercase letters compare different levels of thickness within a settled opacity (comparison of cells in the same row).*

both groups had higher lightness levels than the composite resin groups. No significant difference was observed between the enamel and dentin resin groups, and both groups had higher lightness values than the HT ceramic group.

Analysis of specimens with the same opacity but different thicknesses showed similar lightness levels in the LT ceramic and MO ceramic groups; the highest lightness level was observed for the 1.2 mm thickness groups, while the 1.0 mm and 0.7 mm thickness groups did not differ significantly from each other. The lightness levels of the HT ceramic and enamel resin groups were significantly different, regardless of thickness; the highest lightness levels were observed for the 1.2 mm thickness groups, while the lowest levels were found for the 0.7 mm thickness groups. Finally, in the dentin resin groups, the variation in thickness did not promote any significant change in lightness values.

DISCUSSION

The color of an aesthetic restoration is the result of the interaction between the dental substrate and the restorative material.[17] The final color of dental veneer restorations is influenced by the thickness, translucency and opacity of the restorative material, the type of luting agent, and the type of substrate.[9-11,14,15,18] In the present study, color variability related to the color of the resin cement and of the substrate was minimized by the use of a translucent luting agent and by the discoloration process of the dental substrates, respectively. In addition, the color of the discolored dental fragment was used as the initial color measurement of the specimen, while the final color measurement was taken after the restoration procedures. Thus, the total color variation (ΔE) was analyzed for each specimen.

The use of a spectrophotometer enabled the measurement of color parameters based on the CIE L*a*b* scale. In the initial color assessment, a mean L* value of 69.23 and SD of 0.226 were recorded for the discolored dental fragments. This finding characterizes low variability and hence standardization of the initial color of the dental fragments. Lightness is the most used parameter in the literature to measure discoloration and bleaching of the dental structure.[15] The ΔE values were used for data description and statistical analysis; the higher the ΔE, the greater the difference between the initial and final measurements of the specimens.

At every level of thickness (0.7, 1.0, and 1.2 mm), the lowest translucent ceramic groups (LT and MO) showed the highest ΔE when compared to the HT ceramic group. Conversely, when opacity was considered, there was no statistically significant difference between the LT and MO ceramic groups at each thickness studied. These findings suggest the use of a less opaque material to change the color of a discolored dental substrate. If the lightness values are also considered, the choice of ceramic veneers with LT remains valid, except for the restorations with a thickness of 0.7 mm. In 0.7 mm thick specimens, the ceramic veneer with the highest opaqueness levels exhibited the highest lightness value. Our findings corroborate the results of Hilgert and others,[7] although these authors did not use MO ceramic veneers in their analysis.

In the present study, analysis of the thickness of ceramic veneers showed that the optical properties of laminates with 1.2 mm thickness are different from

those of laminates with thicknesses of 0.7 mm and 1.0 mm, regardless of their translucency. The ΔE values of ceramic veneers with 0.7 mm and 1.0 mm thicknesses did not differ from each other, regardless of the type of ceramic opacity. The HT ceramic veneers had the same lightness levels. As for the LT and MO ceramic veneers, lightness increased with increasing thickness.

Our findings showed that the total ΔE values of the LT and MO ceramic veneer restorations were higher than 3.3—a clinically visible value of tooth color variation.[11] These results support clinical findings showing that an increase in the thickness of ceramic veneers benefits their optical properties when they are used to mask discolored substrates.

The findings of the present study agree with Kürklü and others.[11] According to these authors, opacity, followed by thickness, is the most relevant factor for a satisfactory result in the restoration of a discolored substrate. Therefore, when ceramic veneers are selected for masking discolored substrate restorations, more opaque materials combined with a minimum thickness should be used. In our study, the highest ΔE and lightness values were observed at the thickness of 1.2 mm for each ceramic restoration.

In the present study, when analyzing the properties of the composite resin restorations, the enamel resin (translucency of 15%) showed a significant ΔE in each group, with the highest ΔE value in 1.2 mm thick specimens. Generally, the greater the thickness of the translucent material, the greater it's masking ability, which explains our findings that increasing the thickness of the translucent material resulted in a gradual increase of ΔE. This is true until a certain thickness (known as infinite optical thickness) is reached, at which point the background no longer exerts an influence on the surface color. This assertion is supported by the Kubelka-Munk theory, which proposes that the infinite optical thickness of a restorative material varies according to its thickness and its diffusion and absorption indices for a certain wavelength of the light spectrum.[19] In addition, when lightness was analyzed separately, the value of the enamel resin did not differ from the value recorded for the dentin resin in 1.2-mm thick specimens.

Similar ΔE results (values higher than 3.3) were obtained for the dentin resin veneers (LT − 7%) with thicknesses of 1.0 and 1.2 mm. The dentin resin with 0.7 mm thickness had a mean ΔE value of 4.78, a value higher than those observed for the ceramic and enamel resin veneers. This value was even higher than the critical value, demonstrating the high masking ability of dentin resin restorations on discolored teeth.

Lightness is a measure of the amount of white light present in the specimens. Interestingly, the dentin-shade resin veneer was the restorative material with the highest lightness in specimens with 0.7 mm thickness. In the groups with 1.0 mm thickness, dentin resin as well as the LT and MO ceramic veneers provided the highest lightness values. However, increasing the thickness of these restorative materials to 1.2 mm resulted in a medium performance, which did not differ from the enamel resin lightness values at this respective thickness. Taken together, these findings show that composite resin veneers have a good masking ability when used as restorative materials of discolored teeth.

The aforementioned findings for composite resin veneers differ from the results observed by Darabi and others.[12] These authors stated that one limitation of the use of composite resins is their low ability to modify a discolored surface at a reduced thickness of 1 mm. These differences may be attributed to the different levels of translucency observed in the resinous systems.[12] Therefore, other studies that compare the masking ability of restorative materials using different resinous systems are needed.

Regarding the masking ability of the restorative materials evaluated in the present study, the LT and MO ceramic veneers showed the best ΔE values and lightness variation in 1.2-mm thick specimens. However, it is noteworthy that dentin resin veneers had superior ΔE values and lightness variation in 0.7 and 1.0 mm thick specimens. In addition, in 1.0 mm thick specimens, the lightness of dentin resin veneers was comparable to more opaque ceramic veneers (MO and LT). These findings highlight the potential use of composite resin laminates with small thicknesses as restorative materials of discolored dental substrates. This material may become an even more important approach in minimally invasive dentistry.

CONCLUSION

Based on the methodology used and the data obtained, we conclude that:

- the greater the thickness of the restorative material, the better its ability to mask discolored dental substrates;
- for indirect ceramic restorations, 0.7 and 1.0 mm thick veneers exhibit the same ability to mask discolored dental substrates;
- dentin-shade composite resin veneers with 0.7 and 1.0 mm thickness have the best ability to mask discolored dental substrates; and
- the best thickness/opacity combinations for masking discolored dental substrates were LT and MO ceramic veneers with 1.2 mm thickness.

Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

(Accepted 19 October 2020)

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