

# Masking ability of composite resin and feldspathic porcelain with and without opaquer application for severe tooth discoloration

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## Abstract

**Objective:** This study compared the ability of composite resin and feldspathic porcelain to mask tooth discoloration at different thicknesses, with and without opaquer application.

**Methods:** In this in vitro study, composite resin (VOCO Grandio) and feldspathic porcelain (Noritake Super Porcelain EX-3) specimens (n=20 per material) were prepared in shade A2 at thicknesses of 0.5 and 1.0 mm (n=10 per thickness) and placed over a C4-shade porcelain substrate that simulated a severely discolored tooth. Each specimen was evaluated with and without opaquer application (composite resin opaquer or opaque resin cement, depending on the material). Color was measured according to the CIE Lab\* system, and the color difference ( $\Delta E$ ) was calculated between each specimen under the test condition and the intrinsic reference color of the material. Data were analyzed using three-way ANOVA, with the significance set at  $P < 0.05$ .

**Results:** The porcelain group showed lower  $\Delta E$  values than the composite resin group at both thicknesses, with and without opaquer application. The three-way ANOVA revealed that thickness, opaquer application, and material type each had a significant effect on  $\Delta E$  ( $P < 0.001$ ). The thickness–opaquer interaction was also significant ( $P = 0.04$ ). At 0.5 mm thickness, both opaquer application and material type significantly influenced  $\Delta E$  ( $P < 0.001$ ), whereas at 1.0 mm, the effect of neither factor was significant ( $P = 0.78$  and  $P = 0.83$ , respectively).

**Conclusions:** At a conservative restoration thickness of 0.5 mm, enhanced masking performance was achieved by using feldspathic porcelain instead of composite resin and by applying an opaquer. However, clinically acceptable masking of severe discoloration was not achieved.

**Keywords:** Color, Composite resin, Dental porcelain, Dental veneers, Esthetics, Tooth discoloration

## Introduction

Tooth discoloration is a common esthetic concern in restorative dentistry. Discoloration of the anterior teeth can adversely affect smile appearance and, therefore, patient satisfaction and confidence (1). This condition may be caused by extrinsic deposits, intrinsic alterations, or stains within the tooth structure (2-4).

Tooth discoloration is usually treated with conservative options, such as removal of external stains and bleaching (4). However, these approaches may be insufficient in cases of severe intrinsic discoloration, discoloration associated with structural defects, or

discoloration following previous restorative or endodontic treatment (5). In such cases, various restorative approaches may be used to mask discolored tooth structure, including direct composite resin restorations, indirect composite veneers, porcelain laminate veneers, and full-coverage ceramic crowns, along with adjunctive masking strategies such as composite resin opaquer and opaque resin cement application (5, 6).

Direct composite resin veneers are usually selected for mild to moderate discoloration when a conservative and cost-effective approach is preferred. However, the high translucency of composite resins may allow the underlying discolored substrate to influence the final restoration color in severely discolored teeth (7, 8). In contrast, porcelain laminate veneers are used when greater color stability and more predictable esthetic masking are required. Full-coverage ceramic crowns are generally recommended for severely discolored teeth with large restorations, endodontic discoloration, or inadequate enamel support for veneer bonding (9, 10).

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Ceramic restorations, such as porcelain laminate veneers, offer favorable color stability, fracture resistance, and long-term esthetic performance compared with resin-based restorations. Nevertheless, these materials are more expensive and may require more invasive tooth preparation than composite resin veneers (11).

Opaquers, such as composite resin opaquer (for composite resin restorations) or opaque resin cement (for ceramic restorations), are used as adjunctive materials to enhance masking of a discolored underlying substrate. By increasing the opacity of the restoration, these materials can reduce the influence of a darkened substrate on the final restoration color (12). However, excessive opacity may also compromise the natural translucency of the restoration and result in an artificial appearance (9, 12).

The final appearance of an esthetic restoration is influenced by several factors, including the restorative material, restoration thickness, substrate shade, and the application of an opaquer. Therefore, clinicians must balance effective esthetic masking with the preservation of tooth structure and appropriate restoration thickness, while minimizing the risk of producing an overly opaque restoration (9, 13). Despite extensive research on the translucency and masking ability of composite resins and ceramics, only a few studies have examined the combined effects of opaquers and restoration thickness on the masking ability of these materials. Therefore, this *in vitro* study aimed to compare the masking ability of a composite resin and feldspathic porcelain at different material thicknesses, with and without opaquer application, for severe tooth discoloration.

## Materials and methods

### Study design

The study protocol was approved by the ethics committee of Mashhad University of Medical Sciences (approval code IR.MUMS.DENTISTRY.REC.1399.123).

### Grouping

In this study, two restorative materials were evaluated, including a composite resin and a feldspathic porcelain. All specimens were prepared in shade A2 and tested at two thicknesses: 0.5 mm and 1.0 mm. For each material, 20 specimens were prepared, including 10 specimens with a thickness of 0.5 mm and 10 specimens with a thickness of 1.0 mm. One additional specimen with a thickness of 4.0 mm was prepared to determine the intrinsic color of each material. Each thickness

subgroup was evaluated under two conditions: without opaquer and with opaquer application.

The materials and experimental conditions were as follows:

1. VOCO Grandio composite resin (VOCO GmbH, Cuxhaven, Germany), evaluated at thicknesses of 0.5 mm and 1.0 mm, with and without composite resin opaquer.
2. Noritake Super Porcelain EX-3 feldspathic porcelain (Kuraray Noritake Dental Inc., Tokyo, Japan), evaluated at thicknesses of 0.5 mm and 1.0 mm, with and without opaque resin cement.

### Composite resin specimen preparation

Composite resin specimens were fabricated using split metal molds with central circular cavities 8 mm in diameter. Specimens were prepared at target thicknesses of 0.5 mm and 1.0 mm.

Each metal mold was placed on a glass slab and filled with the composite resin. To minimize internal voids and obtain a smooth surface, the mold was slightly overfilled, covered with a glass slab, and loaded with a 1-kg weight for 10 seconds.

Each specimen was light-cured for 20 seconds from each side using a light-curing unit with an output intensity of 1000 mW/cm<sup>2</sup> (Woodpecker Medical Instrument, Guilin, China). The light intensity was verified using a radiometer before the procedure. After removal from the mold, the composite resin specimens were stored in distilled water at 37°C for 24 hours to allow completion of polymerization.

Specimen thickness was then verified using a digital caliper (CD-6, Mitutoyo, Kanagawa, Japan) and adjusted to the target thickness using fine abrasive discs when required. Both surfaces of each specimen were polished for 20 seconds using aluminum oxide discs (3M ESPE, St. Paul, MN, USA).

### Porcelain specimen preparation

Porcelain specimens were fabricated at dimensions of 8 × 8 mm and target test thicknesses of 0.5 mm and 1.0 mm. The specimens were prepared and then fired in a furnace (Auto Therm 300 VPF; Kousha Fan Pars, Tehran, Iran) according to the manufacturer's recommended firing protocol, including drying, preheating, firing, cooling, and subsequent glazing. After firing, the thickness of each specimen was rechecked using a digital caliper (CD-6; Mitutoyo, Kanagawa, Japan), and the specimens were returned to the furnace for final glazing.

### Simulation of a severely discolored tooth

A standardized discolored substrate was prepared to simulate a discolored tooth background. A C4-shade feldspathic porcelain specimen (Noritake Super Porcelain EX-3; Kuraray Noritake Dental Inc., Tokyo, Japan) was fabricated with dimensions of 8.0 × 8.0 mm and a thickness of 4.0 mm to serve as the standardized discolored substrate. The disc was prepared using the same protocol as the feldspathic porcelain specimens.

### Color assessment protocol

Color measurements were performed using a colorimeter (Chroma Meter CR-400; Konica Minolta Sensing Inc., Osaka, Japan) under a D65 standard illuminant, simulating average daylight conditions. Specimen positioning during color assessment was standardized using a custom-made putty index serving as a positioning jig. A central cavity with a depth of 5 mm was prepared in the putty to ensure fixed and reproducible specimen placement. A standard gray background paper was placed beneath the specimen assembly during all measurements.

The C4-shade porcelain specimen was positioned as the standardized discolored substrate within the putty index, simulating a severely discolored tooth. Each composite resin or porcelain test specimen was placed directly over this substrate, with glycerin applied between the surfaces. Glycerin was used to eliminate air gaps, improve optical coupling, and enhance light transmission between layers (12). The assembled specimens were then centered in the colorimeter for measurement (Figure 1).

Color measurement was performed both with and without opaquer application. For specimens assigned to the opaquer condition, either composite resin opaquer (Creative Color Opaquer; Cosmedent, Inc., Chicago, IL,



**Figure 1.** Positioning of the specimen in a putty index during colorimetric assessment

USA) or opaque resin cement (BISCO, Schaumburg, IL, USA) was applied depending on the material group. For composite resin specimens, two thin layers of opaquer were applied to the back surface of each composite resin specimen using a fine brush and light-cured for 20 seconds according to the manufacturer's instructions. The opaque luting cement was prepared according to the manufacturer's instructions and applied as a thin layer over the feldspathic porcelain specimens.

A 4.0-mm-thick specimen of each material (A2 shade) was prepared and measured over a neutral gray ceramic background with 18% reflectance. This value was used as the intrinsic reference color of composite resin or feldspathic porcelain.

### Measuring the masking ability of materials

For each material, two sets of color coordinate values were recorded. The first set (E1) represented the intrinsic reference color of the material and was obtained from the 4.0-mm-thick specimen prepared from the A2 shade of each material. The second set (E2) represented the color of the test specimens (0.5 mm or 1.0 mm) placed over the C4-shade substrate that simulated a severely discolored tooth. This measurement was performed with and without opaquer application. All color data were recorded using the CIE Lab\* color space system.

The color difference between the intrinsic reference color and each test condition was then calculated to determine the ability of the composite resin or feldspathic porcelain specimens to mask the underlying discoloration. The color difference ( $\Delta E$ ) was calculated as the difference between E2 and E1, using the following equation:

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

In this equation,  $\Delta L^*$ ,  $\Delta a^*$ , and  $\Delta b^*$  indicate the differences in lightness, the red-green color coordinate, and the yellow-blue color coordinate, respectively, between each test condition and the intrinsic reference color of the same material.

### Statistical analysis

Data were entered into IBM SPSS Statistics software, version 21.0 (IBM Corp., Armonk, NY, USA), for statistical analysis. The Shapiro–Wilk test confirmed that  $\Delta E$  values were normally distributed across all material groups, thicknesses, and opaquer conditions ( $P > 0.05$ ). The effects of material type, thickness, and opaquer application, as well as their interactions, were evaluated using three-way analysis of variance (ANOVA). The level of statistical significance was set at  $P < 0.05$ .

**Table 1.** Mean and standard deviation (SD) of  $\Delta E$  values in the composite and porcelain groups according to material thickness and opaquer application

Thickness	Opaquer	composite	porcelain
0.5 mm	Without opaquer	9.6 ± 0.1	7.5 ± 0.5
	With opaquer	8.1 ± 0.8	5.4 ± 0.5
1 mm	Without opaquer	5.6 ± 0.3	5 ± 0.6
	With opaquer	5.1 ± 0.7	4.9 ± 0.6
The effect of thickness		<0.001	
The effect of opaquer		<0.001	
The effect of material type		<0.001	
Interaction effect Thickness*opaquer* material type		0.7	
Interaction effect Thickness*opaquer		0.04	
Interaction effect Thickness*material type		0.06	
Interaction effect opaquer *material type		0.09	

## Results

The mean and standard deviation (SD) of  $\Delta E$  values for the composite resin and porcelain groups are presented in Table 1. The main effects of thickness, opaquer application, and material type were statistically significant ( $P < 0.001$  for all). However, the three-way interaction among thickness, opaquer application, and material type was not statistically significant ( $P = 0.70$ ). Therefore, lower-order interactions were further evaluated.

Among the two-way interactions, only the interaction between thickness and opaquer application was statistically significant ( $P = 0.04$ ), whereas the interactions between thickness and material type ( $P = 0.06$ ) and between opaquer application and material type ( $P = 0.09$ ) were not statistically significant (Table 1).

Table 2 presents the  $\Delta E$  values for the composite resin and porcelain groups according to restoration thickness. According to Table 2, both opaquer application and material type significantly affected  $\Delta E$  values at 0.5 mm ( $P < 0.001$ ). However, the interaction between opaquer

application and material type was not statistically significant ( $P = 0.08$ ). At a thickness of 0.5 mm, feldspathic porcelain showed significantly lower  $\Delta E$  values than composite resin ( $P < 0.001$ ). Furthermore, opaquer application significantly reduced  $\Delta E$  values compared with non-opaquer conditions ( $P < 0.001$ ). At a restoration thickness of 1.0 mm, opaquer application, material type, and their interaction had no significant effect on  $\Delta E$  values ( $P = 0.78$ ,  $P = 0.83$ , and  $P = 0.89$ , respectively).

Table 3 demonstrates the  $\Delta E$  values for the composite resin and porcelain groups based on opaquer application. In both the opaquer and non-opaquer conditions, the effects of thickness and material type, as well as their interaction, were statistically significant ( $P < 0.05$ ). In both conditions, feldspathic porcelain showed significantly lower  $\Delta E$  values than composite resin at a restoration thickness of 0.5 mm ( $P < 0.001$ ), but not at 1 mm ( $P > 0.05$ ; Table 3). Furthermore, increasing restoration thickness improved the esthetic performance of both materials, except for feldspathic porcelain with opaquer application, where no significant

**Table 2.** Comparison of  $\Delta E$  values among the composite resin and porcelain groups according to restoration thickness

Thickness	Opaquer	composite	porcelain	total
0.5 mm	Without opaquer	9.6 ± 0.1	7.5 ± 0.5	8.55 ± 1.11
	With opaquer	8.1 ± 0.8	5.4 ± 0.5	6.75 ± 1.51
	total	8.85 ± 1.04	6.45 ± 1.16	
	The effect of opaquer	< 0.001		
	The effect of material type	< 0.001		
	Interaction effect	0.08		
1 mm	Without opaquer	5.6 ± 0.3	5 ± 0.60	5.30 ± 0.56
	With opaquer	5.1 ± 0.7	4.9 ± 0.60	5 ± 0.66
	total	5.35 ± 0.59	4.95 ± 0.60	
	The effect of opaquer	0.78		
	The effect of material type	0.83		
	Interaction effect	0.89		

**Table 3.** Comparison of  $\Delta E$  values among the study groups according to the use of opaquer

opaquer	Thickness	composite	porcelain	p-value
Without opaquer	0.5	9.6 ± 0.1	7.5 ± 0.5	<0.001
	1	5.6 ± 0.3	5 ± 0.6	0.08
	p-value	< 0.001	<0.001	
	The effect of thickness	< 0.001		
	The effect of material type interaction	< 0.001		= 0.04
With opaquer	0.5	8.1 ± 0.8	5.4 ± 0.5	<0.001
	1	5.1 ± 0.70	4.9 ± 0.6	0.39
	p-value	<0.001	0.058	
	The effect of thickness	<0.001		
	The effect of material type interaction	<0.001		= 0.01

difference was observed between 0.5 mm and 1.0 mm thicknesses ( $P = 0.058$ ; Table 3).

## Discussion

This *in vitro* study compared the ability of a composite resin (VOCO Grandio) and a feldspathic porcelain (Noritake Super Porcelain EX-3) to mask a severely discolored, C4-shade background at two thicknesses (0.5 mm and 1.0 mm), with and without opaquer application. Color coordinates were measured using a colorimeter, and the color difference was calculated between the intrinsic reference color of each material (E1) and the color of the corresponding test specimen after placement over the C4-shade substrate (E2). Accordingly, the  $\Delta E$  values showed how well each material masked the color of the underlying discolored substrate.

The color difference ( $\Delta E$ ) is widely used to quantify how effectively a restoration masks an underlying discoloration. Previous studies have adopted different perceptibility and acceptability thresholds, including values of 2.0, 3.3, and 3.7 (14-17). In the present study, a  $\Delta E$  threshold of 3.3 was used as the criterion for clinical acceptability. Therefore,  $\Delta E$  values below 3.3 were considered clinically acceptable, whereas values equal to or greater than 3.3 were considered clinically unacceptable and perceptible to the human eye (11).

At a thickness of 0.5 mm, the porcelain group showed significantly lower  $\Delta E$  values than the composite resin group. In addition, opaquer application significantly improved the color-masking ability of the restorations at this thickness. However, when the restoration thickness was increased to 1.0 mm, neither material type nor opaquer application had a significant effect on the final color outcome. These findings suggest that the type of restorative material and the use of an opaquer are more influential at reduced restoration thicknesses, whereas

their effects become less pronounced as material thickness increases.

When the groups were compared according to opaquer application, a similar pattern was observed. Under both opaquer and non-opaquer conditions, the difference between the materials was significant only at the 0.5-mm thickness, where feldspathic porcelain demonstrated significantly better masking performance than composite resin. At the 1.0-mm thickness, both materials produced comparable results, regardless of opaquer application. In addition, the two materials demonstrated significantly better masking performance at a restoration thickness of 1.0 mm than at 0.5 mm. The only exception was feldspathic porcelain with opaquer application, for which no significant difference was observed between the two thicknesses. Overall, masking ability improved as restoration thickness increased in both materials. This finding was expected, as thicker restorative layers reduce light transmission from the underlying discolored substrate.

The clinical implication of the present findings is that feldspathic porcelain provides more predictable masking at conservative thicknesses, whereas the masking ability of composite resin is more strongly influenced by material thickness. Furthermore, at lower restoration thicknesses, the use of a composite resin opaquer or opaque luting cement may improve the esthetic appearance of restorations by reducing the influence of the underlying discolored substrate. In contrast, at greater material thicknesses, the additional effect of opaquer application appears to be less pronounced, and the difference between the two restorative materials becomes statistically insignificant.

The composite resin evaluated in the present study was VOCO Grandio, a nanohybrid resin composite used for esthetic direct restorations. The  $\Delta E$  values in the composite resin group were above the clinically

acceptable threshold, indicating that, under the conditions of this study, composite resin could not mask the underlying severe discoloration. The lower masking performance observed in the composite resin group may be a consequence of the optical behavior of resin composites when used over a severely discolored substrate at reduced restoration thicknesses. Resin composites are designed to reproduce the translucency of natural tooth structure; however, in the presence of a dark underlying background, this translucency may allow the substrate color to influence the final restoration shade. Therefore, the final color of a composite resin restoration is affected not only by the selected shade, but also by the thickness and opacity/translucency of the material, as well as the color of the underlying tooth structure (18, 19).

The ceramic evaluated in the present study was a feldspathic porcelain (Noritake Super Porcelain EX-3; Kuraray, Tokyo, Japan), a material that is widely used for laminate veneer restorations (5, 6). Based on the present findings, feldspathic porcelain showed more predictable masking behavior at reduced thicknesses than composite resin. However, the  $\Delta E$  values in the porcelain group remained above the clinically acceptable threshold, indicating that complete masking of severe discoloration was not achieved under the conditions of this study.

In the present study, composite resin showed lower masking performance than feldspathic porcelain at the conservative restoration thickness of 0.5 mm. Although increasing the thickness of composite resin improved its masking ability, this approach may require additional tooth reduction under clinical conditions. This could compromise enamel preservation, increase the risk of dentin exposure and postoperative sensitivity, and reduce the predictability of adhesive bonding (20). Previous studies similarly attributed the lower thickness sensitivity of ceramics to their optical structure, in which translucency and masking behavior remain comparatively favorable at reduced thicknesses (21, 22).

The outcomes of this study are consistent with the findings of Darabi et al. (23), who reported that composite resins at thicknesses of 0.5, 1.0 and 1.5 mm could not mask a dark background. Moreover, Kim et al. (24) found that none of the five composite resin materials tested could mask discoloration at thicknesses ranging from 0.5 to 4.0 mm. In contrast, Ryan et al. (25) found that the masking effect was acceptable only at 2.0 mm thickness, with no significant difference between 0.5 mm and 1.0 mm thicknesses. An et al. (26) reported that the minimum thickness required for composite

resin materials to mask a C4 background ranged from 0.8 to 1.45 mm. Differences among studies regarding the appropriate thickness may be explained by differences in methodology.

In the present study, neither composite resin nor feldspathic porcelain was capable of effectively masking the underlying discoloration, regardless of restoration thickness or opaquer application. This finding is consistent with the results of Wayakanon et al. (27), who found that no ceramic-cement combination achieved clinically acceptable masking of severe discoloration, with substrate shade explaining approximately 88% of the color variation and translucency and cement shade having only minor effects. Saláta et al. (28) reported that a ceramic thickness of 0.5 mm was insufficient to achieve clinically acceptable masking, regardless of the translucency level. In their study, acceptable masking was observed only with low-translucency ceramic at a thickness of approximately 1.5 mm. Boscato et al. (29) indicated that feldspathic porcelain showed better masking ability at greater thicknesses but did not achieve clinically acceptable masking over a C4-shade substrate at either 0.5 or 1.0 mm. In contrast to the findings of this study, Pala et al. (9) found that acceptable masking could be achieved at thicknesses as low as approximately 0.4 mm when a low-translucency ceramic was used in combination with tooth-colored cement. Begum et al. (30) found that opaque luting cement improved the masking ability of lithium disilicate ceramic over a C3-shade composite background compared with translucent cement. Xing et al. (21) reported successful masking of a C2-shade background using 0.5-mm-thick lithium disilicate ceramic with opaque cement. The more favorable outcomes in these studies may be explained by the use of lighter backgrounds and differences in opaque cement protocols.

This study has some limitations. As an *in vitro* study, it could not fully reproduce the optical and clinical conditions of the oral environment. Another limitation of this study is that only one type of opaquer and one type of each restorative material were tested. Future studies should evaluate various restorative materials and opaques to better clarify their effects on masking ability.

## Conclusions

Under the conditions of this study:

- 1- The  $\Delta E$  values in the composite resin and porcelain group remained above the clinically acceptable threshold of 3.3, regardless of restoration

thickness or opaquer application. This indicates that complete masking of severe discoloration was not achieved under the conditions of this study.

- 2- At a restoration thickness of 0.5 mm, the porcelain group showed significantly lower  $\Delta E$  values than the composite resin group. In addition, opaquer application significantly improved the color-masking ability of the restorations at this thickness. When the restoration thickness was increased to 1.0 mm, neither material type nor opaquer application had a significant effect on the final color outcome.
- 3- The two materials demonstrated significantly better masking performance at a restoration thickness of 1.0 mm than at 0.5 mm. The only exception was feldspathic porcelain with opaquer application, for which no significant difference was observed between the two thicknesses.

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## Conflict of interest

The authors declare no conflict of interest.

## Author contributions

H.C. contributed to the conceptualization, validation, and supervision of the study. R.S. contributed to the methodology and the writing of the original draft. S.Z.J. contributed to data analysis, data interpretation, and manuscript revision. A.S.L. contributed to study supervision, data interpretation, and the writing of the original draft of the manuscript. All authors reviewed and approved the final version of the manuscript.

## Ethical considerations

The protocol was approved by the Ethics Committee of the Faculty of Dentistry, Mashhad University of Medical Sciences, under approval code IR.MUMS.DENTISTRY.REC.1399.123.

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