

Masking Ability and Color Stability of Resin Composites with Different Layering Techniques on Discolored Tooth at Immediate Restoration and After Thermocycling

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Research Article

Abstract

The purpose of this study was to evaluate the masking ability and color stability of resin composites, restored with various layering techniques on discolored tooth at immediate restoration and after thermal aging. For the materials and methods, three hundred and forty disc-shaped specimens of dentin shade and enamel shade of four brands of resin composite included Filtek Z350 XT, Harmonize, Ceram XDuo, and Estelite Σ Quick were prepared with five layering thicknesses in millimeters ($n=17$) as followed (Dentin thickness/Enamel thickness): 0.3/0.3, 0.4/0.4, 0.5/0.3, 0.5/0.5 and 0.7/0.3. The masking ability was interpreted through the color difference of resin composites on A4-shade tooth background at immediate restoration (ΔE_{T0}) and after thermocycling (ΔE_{T1}), and the color stability of specimens was measured on A1-shade inherent color background (ΔE_{A1}) using CIELab coordinates obtained from a spectrophotometer. Thermocycling was performed at 5°C and 55°C in distilled water for 5,000 cycles. Kruskal-Wallis test and Dunn's Bonferroni post hoc test, and Wilcoxon matched-pairs signed rank test were used to determine the significant difference of color difference ($p<0.05$). The results showed that the median color difference of the layered specimens (ΔE_{T0} , ΔE_{T1} , and ΔE_{A1}) were as follow; Filtek Z350 XT (1.52-2.00, 1.40-1.87, and 0.94), Harmonize (2.19-5.82, 2.34-5.65, and 1.36), Ceram XDuo (1.26-2.65, 2.13-2.45, and 1.28) and Estelite Σ Quick (3.80-7.70, 4.07-8.10, and 1.16). ΔE_{T0} and ΔE_{T1} were significantly different amongst resin composites with layering technique. Moreover, thermocycling significantly affected to the masking ability and the resin composite brands affected to the color stability (ΔE_{A1}) after thermocycling in some layering thicknesses ($p<0.05$). In conclusion, all resin composite brands demonstrated higher masking ability when increasing the thickness except for Filtek Z350 XT. A minimum 0.6 mm thickness of Filtek Z350 XT and Ceram XDuo, and 1.0 mm of Harmonize can mask the discolored tooth, whereas Estelite Σ Quick showed unacceptable masking ability at all thicknesses. The color stability of all resin composites was clinically acceptable. Filtek Z350 XT showed the highest color stability.

Keywords: Resin composite/ Layering technique/ Masking ability/ Color stability/ Discolored tooth

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Introduction

Tooth discoloration was one of the most common issues in cosmetic dentistry since this change impacted the confidence, personality, and social interaction of patients.^{1,2} Worth noting is that recently direct composite veneer was popularly implemented for correcting the tooth size, tooth color, and tooth alignment as it presented excellent esthetic outcome, acceptable durability, tooth structure preservation, as well as it was budget-saver than ceramic veneer. It is thus recommended for the young adult patients with large pulp,

and the patient with financial issue.³⁻⁵ Generally, tooth preparation for direct restoration is limited to the enamel in accordance with the minimally invasive tooth preparation. In case of severe discoloration, more tooth preparation or more opacity of resin composite were recommended, while in case of, an optimal tooth preparation in combination with layering technique was a treatment of choice for restoring and masking of non-severely discolored teeth.^{1,6-9}

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To simulate the natural tooth and surrounding structure which presents complex color and translucency, layering technique using resin composites with different optical properties is recommended.¹⁰ Optical property and color of resin composite were influenced by the tooth background and oral environment.¹¹ An opaque shade of the selected resin composite is first used to mask the discoloration or dark background, while final facing with the translucent shade is aimed to simulate the natural esthetics to obtain clinically acceptable outcomes.¹¹ Moreover, the translucency of opaque shade decreases as the thickness increases.¹² Minimal tooth preparation relating to the enamel depth of natural tooth (0.3-0.5, 0.6-1.0 and 1.0-2.1mm for cervical, middle, and incisal area, respectively)¹³ simultaneously with the layering technique of resin composite veneer is advocated for masking the discolored tooth.¹² Nonetheless, the longevity of resin composite restoration and its color stability may compromise long-term esthetic appearance and alter its masking effects on the discolored tooth background.

Esthetic properties of resin composite restoration are affected after prolonged aging, for instance a hydrolytic degradation may also alter the translucency and color of resin composite.¹⁴ Long-term studies using a relatively short storage period indicated that the major changes in color occurred in the first days after polymerization.¹⁵ Several studies have assessed the changes in optical properties of materials following temperature change simulation processes (thermocycling) involving 2,000 cycles^{16,17}, 3,000 cycles¹⁸, and 5,000 cycles¹⁹. The results indicated that the ΔE values varied depending on the composite resin used. However, it was consistently observed that the translucency parameters decreased after undergoing temperature change simulations. In a study by Lee et al.¹⁹, the effects of temperature change simulation on the optical properties of composite resins were evaluated. They found that 5,000 cycles, equating to six months of clinical use, significantly impacted the color and translucency of the materials.

Previous studies on the masking ability of composite resins over dark backgrounds have provided valuable insights. For instance, Kim et al.¹² investigated the translucency and masking ability of various opaque composite resins. They evaluated the sufficient thickness of

opaque composites in scenarios involving dark backgrounds, such as black oral cavities and discolored tooth structures. Their findings indicated that the thickness required to effectively mask a C4 background was between 0.5 and 1.0 mm, while for a black background, it ranged from 1.0 to 2.0 mm. In a related study, An et al.²⁰ examined the continuous increase in thickness of opaque composite resins on their masking ability. They determined the minimum thickness necessary for the composite to effectively cover discolored tooth structures or black backgrounds, reporting that 0.80 to 1.45 mm was required for a C4 background and 1.85 to 2.00 mm for a black background. These studies focused solely on opaque composite resins; however, anterior tooth restorations often require a combination of materials with varying opacities. Thus, the thickness of each layer becomes crucial when aiming for adequate masking and achieving a natural aesthetic. Additionally, Miotti et al.²¹ investigated the masking ability of composite resins applied in a layering technique at a final thickness of 1.5 mm. They found that the Filtek Z350XT, restored using a layered approach with the following combinations: A1 Dentin shade at 1.5 mm, A1 Dentin shade at 1 mm combined with A1 Body shade at 0.5 mm, and A1 Dentin shade at 1 mm combined with A1 Enamel shade at 0.5 mm, effectively masked a C4 discolored tooth in a clinically acceptable manner.

However, there were still not sufficient evidence on the masking ability of resin composite on non-severe, discolored tooth. Therefore, this recent study aimed to study the masking ability of various resin composite shades with different layering thickness at immediately restored and after thermocycling and also the color stability of restoration. The research null hypotheses of this study were: (1) Resin composites with different layering technique would not affect to the masking ability of restoration at before and after thermocycling; (2) Thermocycling would not affect to the masking ability of resin composites with different layering technique; (3) No difference between the color stability of resin composite brands after thermocycling.

Materials and methods

This study was conducted as an experimental study to compare the masking ability of resin composites at the different thicknesses of combined enamel-dentin layering technique on the moderately discolored tooth. The masking ability on natural tooth and the color stability were measured by color difference (ΔE) at a time before and after thermocycling. There will be no color differences (ΔE) if the masking ability is perfect. A color difference in the range of 3.3 was considered clinically acceptable.²² The CIELab coordinates for color difference (ΔE) was obtained by a spectrophotometer (ColorQuest XE, Hunter associates Laboratory, Inc. Virginia, USA)

Sample size calculation

Statistical values from a pilot study comparing the masking ability of four brands of composite resins at various layering technique ($\mu_1=1.70$, $\mu_2=1.18$, $\sigma_1=0.65$, $\sigma_2=0.07$) were inputted to G*power 3.1 software (Heinrich-Heine-Universität, Düsseldorf, Germany) with a power of test = 0.90 and α error = 0.05. The sample size was calculated and employed 17 specimens per group.

Fabrication of resin composite discs

Four commonly used brands of resin composite with different compositions: FTK: Filtek Z350 XT (3M-ESPE, USA), HNZ: Harmonize (Kerr, USA), CXD: Ceram X Duo (Dentsply, Germany) and ESQ: Estelite Σ Quick (Tokuyama, Japan) were used as shown in Table 1. Disc-shape specimens (6-mm diameter) were prepared from each resin composite brand and allotted to five layering thickness groups (n=17, N=340) as follows.

Group 1: 0.3/0.3; Dentin shade 0.3 mm and Enamel shade 0.3 mm

Group 2: 0.4/0.4; Dentin shade 0.4 mm and Enamel shade 0.4 mm

Group 3: 0.5/0.3; Dentin shade 0.5 mm and Enamel shade 0.3 mm

Group 4: 0.5/0.5; Dentin shade 0.5 mm and Enamel shade 0.5 mm

Group 5: 0.7/0.3; Dentin shade 0.7 mm and Enamel shade 0.3 mm

The thickness categorization was related to the enamel depth of natural tooth (0.3-0.5, 0.6-1.0 and 1.0-2.1 mm for cervical, middle, and incisal area, respectively)¹³

The specimens were prepared by customized cylindrical metallic devices, measuring 6.0 mm in diameter and different thicknesses. Two-layer specimens were prepared by first obtaining dentin shade at a desired thickness and covered with glass plate to flatten and smoothen the surface, then light curing was performed using a light-emitting diode (LED, Demi Plus, Kerr, USA) with 1,200 mW/cm² irradiance. The glass plate was removed, and the second enamel shade layer was subsequently placed on top. The final layer was again covered with the glass plate and finally light-cured. Each layer was light-cured for 40 seconds on upper surface of the specimens. The final A1 color of each brand was achieved by the combination of dentin and enamel shade as suggested by manufacturer recommendation as shown in Table 1. Thickness consistency of each layer was confirmed with digital vernier caliper (Mitutoyo 500, Mitutoyo Corporation, Kanagawa, Japan). All specimens were stored in 37°C and 90% relative humidity-controlled cabinet (Climatic test cabinet, Nuve TK120, UK) until further analysis.

Table 1 The materials used in the study

Brand/type	Shade	Manufacturer	Composition	Lot no.
Filtek Z350 XT/ Nanofill (FTK)	A1E A2D	3M-ESPE, St. Paul, MN, USA	Resin matrix: Bis-GMA, UDMA, Bis-EMA, TEGDMA, PEGDMA Inorganic filler: silica filler (20 nm), zirconia filler (4-11 nm), aggregated zirconia/silica cluster filler (0.6-10 μ m) Filler loading: 63.3vol%/ 78.5wt%	NA71222 NA90199
Harmonize/ Nanohybrid (HNZ)	A1E A1D	Kerr corporation, Orange, CA, USA	Resin matrix: BisGMA, BisEMA, TEGDMA Inorganic filler: nano-scale spherical silica and zirconia particles (5-30 nm), barium glass particles Filler loading: 64.5vol%/ 81wt%	7282947 7594901
Ceram X Duo/ Nanohybrid (CXD)	E2 D1	Dentsply DeTrey, GmbH, Konstanz, Germany	Resin matrix: Methacrylate modified polysiloxane, Dimethacrylate resin, Camphorquinone, Ethyl (dimethyl-amino) benzoate Inorganic filler: Barium-aluminium-borosilicate glass (1.2-1.6 μ m), Methacrylate functionalised silicon dioxide nano filler (2.3 nm) Filler loading: 57vol%/ 76wt%	2009000377 2010000296
Estelite Σ Quick/ Supra-nanofill (ESQ)	A1 OA1	Tokuyama Dental Co., Tokyo, Japan	Resin matrix: Bis-GMA, TEGDMA Inorganic filler: silica-zirconia filler, composite filler (0.1-0.3 μ m) Filler loading: 71vol%/ 82wt%	E2823 W7973

Background preparation

Two background shades (A4-central incisor, and A1-dentin shade of resin composite) were used to determine the masking ability and color stability. A4-central incisor was used as a representative of moderately discolored tooth, and the A1-dentin shade of each individual brand was used as an inherent color background. The study involved the use of tooth specimens, which were exempt from ethical approval as they were obtained from de-identified sources and this aligns with institutional guidelines regarding the use of biological materials in research.

The A4-shade natural central incisor was initially inspected by an intraoral spectrophotometer (Vita Easyshade V, Vita Zahnfabrik, Germany). The tooth crown was cut and embedded in an epoxy resin block. The labial surface was ground by Ecomet3 (Buehler, Germany) followed by silicon carbide abrasive paper no. 600 and 800, respectively (Figure 1).

The A1-inherent dentin shade resin composite was prepared as a disc shape (6 mm diameter, and 5 mm thickness) from each brand, in the acrylic mold (Figure 1). The glass slip was placed on top of materials and the resin composite was cured for 40 seconds by a light-emitting diode (LED, Demi Plus, Kerr, USA) similarly on both top and bottom of samples.

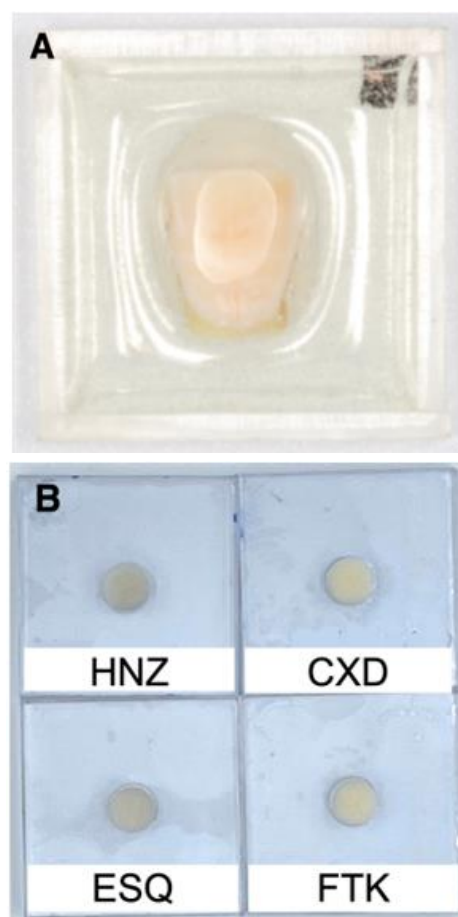


Figure 1 Two background used in this study. The A4 central incisor background (A) and A1 inherent color of each resin composite (B).

Color measurement

Each specimen was analyzed over two different backgrounds, with a glycerin to simulate the oral environment.²³ The color measurement of specimens was performed according to the CIELab system for D65 standard light source, 10% observer angle, 100% UV, and a standard wavelength of 380-780 nm on a white background ($L^* = 96.7$, $a^* = 0.1$, $b^* = 0.2$) using a spectrophotometer (ColorQuest XE, Hunter associates Laboratory, Inc. Virginia, USA) (Figure 2). To calibrate the machine before testing, a standard white tile ($L^*=96.7$, $a^*=0.1$, $b^*=0.2$) was used.

The CIE1976 were used, based on L^* , a^* , and b^* coordinates. The color difference on different background at immediate restoration (ΔE_{T0}) and after thermocycling (ΔE_{T1}) was calculated as follows (Equation 1, and 2) as previously reported.²⁴

$$\Delta E_{T0} = [(\Delta L_1^*)^2 + (\Delta a_1^*)^2 + (\Delta b_1^*)^2]^{1/2} \dots \dots \text{(Equation 1)}$$

$$\Delta E_{T1} = [(\Delta L_2^*)^2 + (\Delta a_2^*)^2 + (\Delta b_2^*)^2]^{1/2} \dots \dots \text{(Equation 2)}$$

Where ΔL_1^* , Δa_1^* , and Δb_1^* corresponds to lightness, green-red, and blue-yellow differences of A4 tooth background and A1 inherent resin composite backgrounds at immediately restored, respectively, and ΔL_2^* , Δa_2^* , and Δb_2^* were achieved after thermocycling.

The color difference for color stability (ΔE_{A1}) was calculated as follows.²⁴ (Equation 3).

$$\Delta E_{A1} = [(\Delta L_{A1}^*)^2 + (\Delta a_{A1}^*)^2 + (\Delta b_{A1}^*)^2]^{1/2} \dots \dots \text{(Equation 3)}$$

Where ΔL_{A1}^* , Δa_{A1}^* , and Δb_{A1}^* corresponds to lightness, green-red, and blue-yellow differences of A1 inherent color backgrounds before and after thermocycling. A threshold of $\Delta E < 3.3$ were considered clinically acceptable. Color difference values above these thresholds can be visualized by a layman and cannot be considered acceptable.^{12, 25, 26}

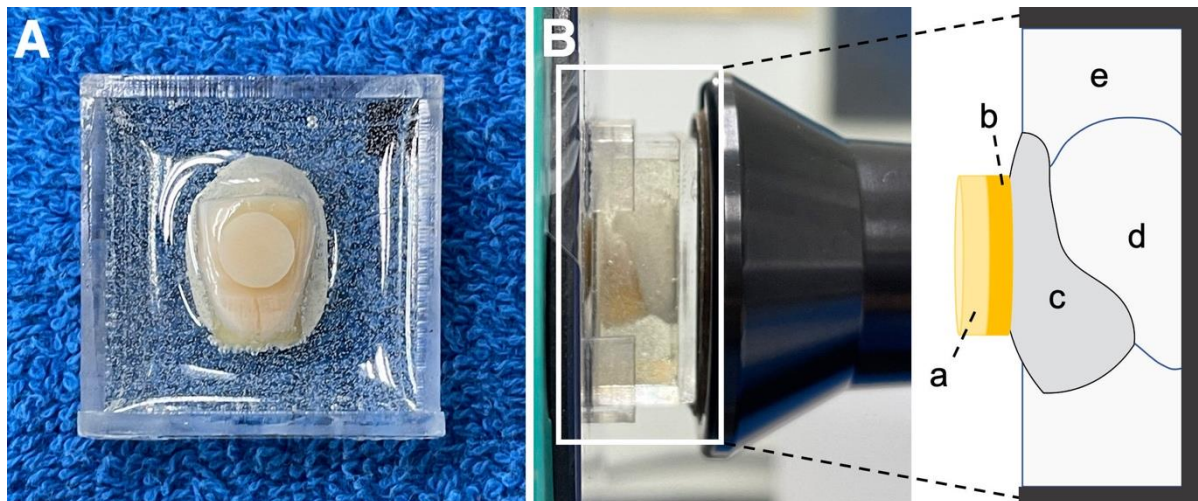


Figure 2 The layering composite resin on the A4 discolored tooth background (A). The schematic of specimens for masking ability test (B): (a) enamel shade, (b) dentin shade, (c) A4 discolored tooth background, (d) acrylic resin mount, (e) epoxy resin

Thermocycling

Thermocycling was performed on the specimens for 5,000 cycles in distilled water at 5°C and 55°C with a dwell time of 15 seconds mimicking 6 months of clinical service according to Lee et al¹⁹ in a machine (Thermocycling, KMITL, TC301, HWB332, Thailand), and color was measured after blotting dry. The testing workflow was shown in Figure 3.

Statistical analysis

The descriptive analysis was performed by median, interquartile range (IQR) on all color difference values. The test of normality of color difference values at immediately

restored (ΔE_{T0}), after thermocycling (ΔE_{T1}), the difference before and after thermocycling, and color stability (ΔE_{A1}) were done and non-normalized distribution were presented. The non-parametric test was then utilized, the values of ΔE_{T0} , ΔE_{T1} , ΔE_{A1} of each layering technique of different resin composites were subjected to Kruskal-Wallis test and Dunn's Bonferroni post hoc test, and Wilcoxon matched-pairs signed rank test was performed to compared the color difference values before (ΔE_{T0}) and after thermocycling ΔE_{T1} . Statistically significant difference was defined at $p < 0.05$ using SPSS 20 software (IBM, USA).

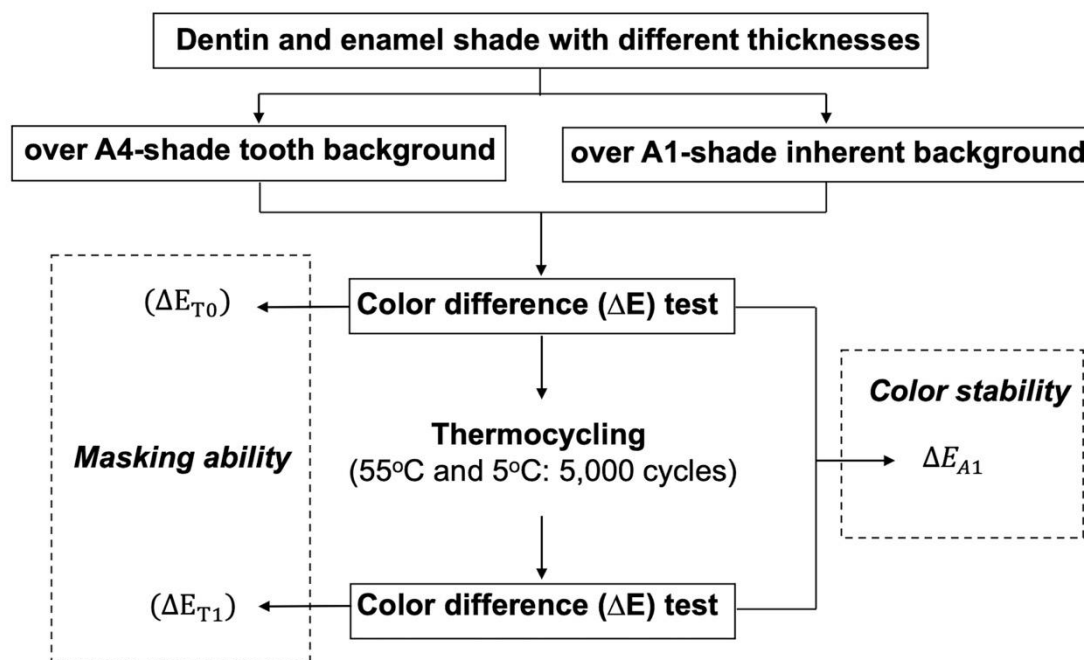


Figure 3 The testing workflow

Results

Color difference of resin composite shades with various thicknesses of layering technique at immediately restored (ΔE_{T0})

The median, and interquartile range (IQR) of color difference (ΔE_{T0}) of different resin composite shades with various layering thicknesses at immediate restoration were shown in Table 2 and Figure 4.

According to the color difference on A4 background (ΔE_{T0}), Filtek Z350 XT and Ceram X Duo at all layering thicknesses, and Harmonize at 0.5/0.5 and 0.7/0.3, showed the clinically acceptable limit of human detection ($\Delta E_{T0} \leq 3.3$); however, Estelite Σ Quick at all layering thicknesses showed unacceptable masking ability ($\Delta E_{T0} > 3.3$).

The lowest color difference value on A4 background (ΔE_{T0}) was presented in CXD0.7/0.3 and CXD0.5/0.3 which were 1.26 and 1.38, respectively. On the other hand, the highest color difference value on A4 background (ΔE_{T0}) was seen in ESQ0.3/0.3 and HNZ0.3/0.3, which were 7.70 and 5.82, respectively. The masking ability of all resin composites shades was likely to improve while increasing the overall thickness of resin composites, except for Filtek Z350 XT.

Based on each resin composite shade, the Kruskal-Wallis test showed that there was an influence of different layering thicknesses on the masking ability. The Dunn's Bonferroni post hoc test showed no statistical difference amongst all groups except between HNZ0.3/0.3-HNZ0.5/0.5, and HNZ0.3/0.3-HNZ0.7/0.3, CXD0.3/0.3-CXD0.5/0.3, CXD0.3/0.3-CXD0.5/0.5, and CXD0.3/0.3-CXD0.7/0.3.

Color difference of resin composite shades with various thicknesses of layering technique after thermocycling (ΔE_{T1})

The median, and interquartile range (IQR) of color difference (ΔE_{T1}) of different resin composite shades with various layering thicknesses after thermocycling were presented in Table 2 and Figure 5.

According to the color difference on A4 background (ΔE_{T1}), Filtek Z350 XT and Ceram X Duo at all layering thicknesses, and Harmonize at 0.5/0.5 and 0.7/0.3, showed the clinically acceptable limit of human detection ($\Delta E_{T1} \leq 3.3$); however, Estelite Σ Quick at all layering thicknesses showed unacceptable masking ability ($\Delta E_{T1} > 3.3$).

The lowest color difference value on A4 background (ΔE_{T1}) was presented in CXD0.7/0.3, CXD0.5/0.5, and FTX0.3/0.3 which were 1.23, 1.40, and 1.40, respectively. On the other hand, the highest color difference value on A4 background (ΔE_{T1}) was seen in ESQ0.3/0.3 and HNZ0.3/0.3, which were 8.10 and 5.65, respectively.

The masking ability of all resin composite brands was likely to improve while increasing the overall thickness of resin composite, except for Filtek Z350 XT.

Based on each resin composite shade, the Kruskal-Wallis test showed that there was an influence of different layering thicknesses on the masking ability. The Dunn's Bonferroni post hoc test presented that there was no statistical difference amongst all groups except between HNZ0.3/0.3-HNZ0.5/0.5, and HNZ0.3/0.3-HNZ0.7/0.3, CXD0.3/0.3-CXD0.5/0.5, CXD0.3/0.3-CXD0.5/0.5, and CXD0.3/0.3-CXD0.7/0.3.

The difference of color difference of resin composites with various layering thicknesses before and after thermocycling (ΔE_{T0} and ΔE_{T1})

The color difference of all resin composite brands was likely to decrease after thermocycling. Wilcoxon matched-pairs signed rank test showed no significant difference between the color difference (ΔE_{T0} and ΔE_{T1}) of all resin composite shades at before and after thermocycling, except FTX0.4/0.4, FTX0.7/0.3, HNZ0.4/0.4, HNZ0.5/0.3, HNZ0.7/0.3, ESQ0.4/0.4 as shown in Figure 6.

Color stability of resin composite shades after thermocycling (ΔE_{A1})

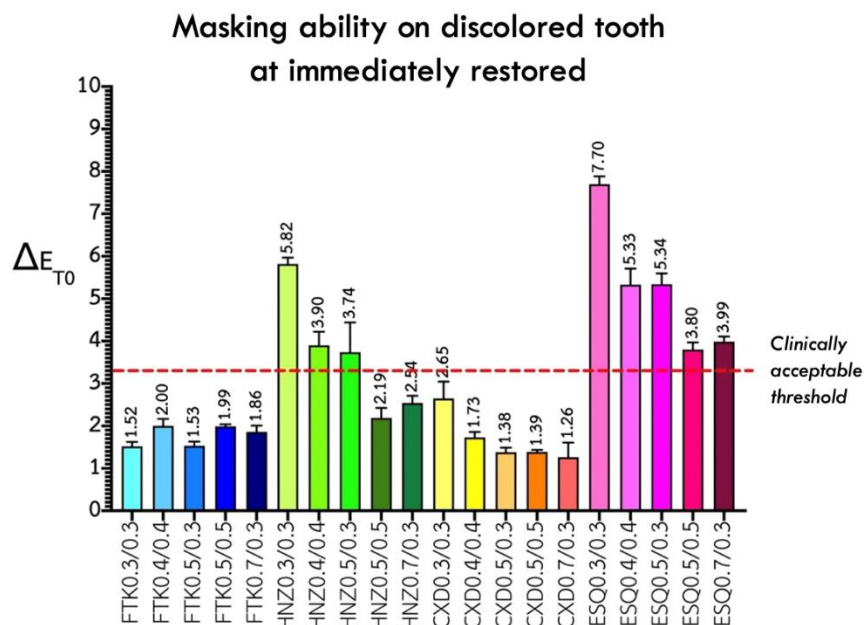
The color stability (ΔE_{A1}) of all resin composite shades demonstrated a clinically acceptable at $\Delta E_{A1} < 3.3$. The lowest color difference value (ΔE_{A1}) was found in Filtek Z350 XT (0.94) whereas the highest color difference value was found in Harmonize (1.36) as seen in Table 2 and Figure 7.

The Kruskal-Wallis test showed that there was an influence of resin composite brands on a color stability (ΔE_{A1}) ($p < 0.05$). Dunn's Bonferroni post hoc test showed that there was significantly different of color stability (ΔE_{A1}) amongst groups except between HNZ-CXD, HNZ-ESQ, and CXD-ESQ (Table 2).

Table 2 The color difference (ΔE) of resin composites with various layering thicknesses

Resin Composite	Layering Thickness (Dentin/Enamel)	ΔE_{T0} (immediately restored) Median (IQR)	ΔE_{T1} (after thermocycling) Median (IQR)	Color stability (ΔE_{A1}) Median (IQR)
Filtek Z350 XT (FTK)	0.3/0.3	1.52 (1.43–1.63) ^A	1.40 (1.35–1.51) ^A	0.94 (0.66–1.29) ^a
	0.4/0.4	2.00 (1.84–2.17) ^A	1.60 (1.56–1.72) ^B	
	0.5/0.3	1.53 (1.42–1.63) ^A	1.53 (1.43–1.77) ^A	
	0.5/0.5	1.99 (1.83–2.04) ^A	1.87 (1.73–1.96) ^A	
	0.7/0.3	1.86 (1.76–2.01) ^A	1.48 (1.35–1.54) ^B	
Harmonize (HNZ)	0.3/0.3	5.82 (5.60–5.97) ^A	5.65 (5.49–5.74) ^A	1.36 (1.08–1.72) ^b
	0.4/0.4	3.90 (3.58–4.22) ^A	3.45 (3.27–3.52) ^B	
	0.5/0.3	3.74 (3.52–4.44) ^A	3.57 (3.37–3.69) ^B	
	0.5/0.5	2.19 (2.15–2.43) ^A	2.34 (2.26–2.59) ^A	
	0.7/0.3	2.54 (2.44–2.71) ^A	2.43 (2.31–2.57) ^B	
Ceram X Duo (CXD)	0.3/0.3	2.65 (2.37–3.05) ^A	2.45 (2.35–2.66) ^A	1.28 (0.73–1.98) ^b
	0.4/0.4	1.73 (1.56–1.86) ^A	1.63 (1.55–1.69) ^A	
	0.5/0.3	1.38 (1.33–1.49) ^A	1.42 (1.32–1.55) ^A	
	0.5/0.5	1.39 (1.34–1.44) ^A	1.40 (1.31–1.47) ^A	
	0.7/0.3	1.26 (1.20–1.61) ^A	1.23 (1.17–1.29) ^A	
Estelite Σ Quick (ESQ)	0.3/0.3	7.70 (7.56–7.89) ^A	8.10 (7.79–8.28) ^B	1.16 (0.92–1.75) ^b
	0.4/0.4	5.33 (5.11–5.71) ^A	4.80 (4.62–4.98) ^B	
	0.5/0.3	5.34 (5.24–5.60) ^A	5.55 (5.20–5.76) ^A	
	0.5/0.5	3.80 (3.54–3.97) ^A	3.83 (3.59–3.94) ^A	
	0.7/0.3	3.99 (3.90–4.11) ^A	4.07 (3.91–4.20) ^A	

Same lowercase letter showed no significant difference among groups in a column and same uppercase letter showed no significant difference between groups in a row ($p > 0.05$)

**Figure 4** The masking ability on discolored tooth at immediately restored via the color difference values (ΔE_{T0}) (The asterisk (*) showed the significant difference between groups)

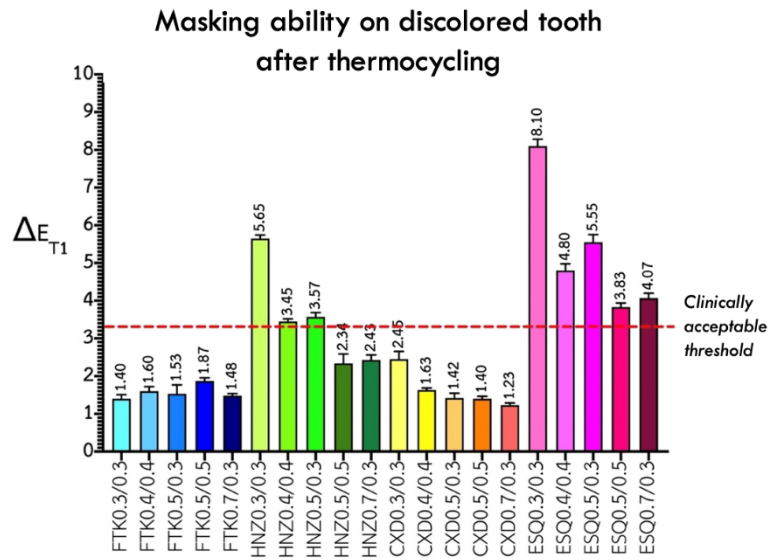


Figure 5 The masking ability on discolored tooth after thermocycling via the color difference values (ΔE_{T1})

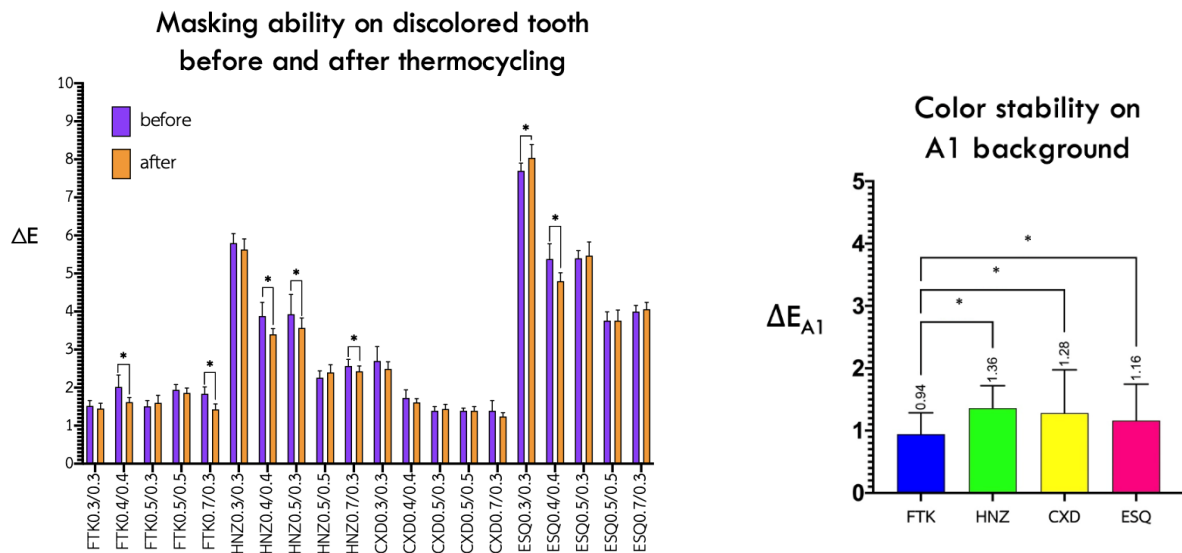


Figure 6 The masking ability on discolored tooth before and after thermocycling via the color difference values (ΔE_{T0} and ΔE_{T1} , respectively) (The asterisk (*) showed the significant difference between groups)

Figure 7 The color stability on A1 background via the color difference values (ΔE_{A1}) (The asterisk (*) showed the significant difference between groups)

Discussion

This study aimed to compare the masking ability of four resin composite brands with different layering thickness on a moderately discolored tooth at before and after thermocycling, and investigate the color stability of restoration. Our result showed that resin composites with different layering techniques, significantly affected to the masking ability of restoration at before and after thermocycling on discolored tooth, so that the first null hypothesis was rejected. Moreover, in this study, the thermocycling significantly affected to the masking ability of resin composites with different layering technique in some thicknesses, so that the second null hypothesis was partially rejected. Concerning the color stability, there was significant difference amongst the color stability of resin composite brands after thermocycling, so that the third null hypothesis was rejected.

The final thickness of resin composites used in this recent study was consistent with enamel depth of natural tooth (0.3-0.5, 0.6-1.0 and 1.0-2.1 mm for cervical, middle, and incisal area, respectively).¹³ Ferrari et al suggested that 0.5 mm was a minimum thickness for veneering restoration.¹³ To mimic the moderate discoloration, A4-shade was selected since the value and chroma of A4-shade was less than that of C4-shade which usually used to represent severe discoloration.²⁷ To examine the masking ability of resin composites on the non-severely discolored teeth, our study model was in agreement with an earlier report of Farhan et al, that measured the masking ability of ceramic veneer on A1- and A4-shade background.²⁸

At immediately restored, the masking ability of resin composites was improved when increasing the entire thickness as indicated by the reduction of color difference value (ΔE_{T0}). ΔE_{T0} of layering technique was significantly different for all resin composite brands except for Filtek Z350 XT. Filtek Z350 XT and Ceram X Duo at all thicknesses (0.6-1 mm) and Harmonize at 1 mm could mask the A4-shade background with clinically acceptable limit ($\Delta E_{T0} \leq 3.3$). On

the other hand, the masking ability of Estelite Σ Quick at all thicknesses could not be practically acceptable.

While the enamel shade thickness was controlled at 0.3 mm, the increasing of dentin shade thickness might not affect to the color difference (ΔE_{T0}) as shown in Harmonize at 0.5/0.3 and 0.7/0.3, Ceram X Duo at 0.5/0.3 and 0.7/0.3, and Estelite Σ Quick at 0.5/0.3 and 0.7/0.3. This argued with other study showing that the masking ability of layering resin composite was influenced by the variation of dentin shade thickness.^{12, 20} We found that the thickness of enamel shade might also play an important role in masking ability. When limiting the dentin shade thickness at 0.5 mm, an increase of enamel shade thickness led to the decrease of color difference value (ΔE_{T0}) as shown in Harmonize at 0.5/0.3 ($\Delta E_{T0} = 3.74$) and 0.5/0.5 ($\Delta E_{T0} = 2.19$), and Estelite Σ Quick at 0.5/0.3 ($\Delta E_{T0} = 5.34$) and 0.5/0.5 ($\Delta E_{T0} = 3.80$). However, this effect was not significantly different. It is possible that the enamel shade affected to the masking ability of layering technique²⁹, and the small variation of thickness of enamel shade has a stronger effect on masking ability than that of dentin or body shade.³⁰ However, the reduction of color difference by the alteration of enamel shade thickness could not be seen in Ceram X Duo at 0.5/0.3 ($\Delta E_{T0} = 1.38$) and 0.5/0.5 ($\Delta E_{T0} = 1.39$). This might be attributed by the different translucency, component, and microstructure of different materials used in this study. In addition, to strongly confirm the effect of dentin and enamel shade on masking ability of layering composite resin, a specific and focused research design should be further conducted.

Considering the Filtek Z350 XT, there was no statistical difference of masking ability amongst the layering thicknesses ($p > 0.05$) and all groups could mask the A4-discolored tooth in clinically acceptable level ($\Delta E_{T0} < 3.3$), similar to a previous study of Kamishima et al.³⁰ The composition and translucency of enamel and dentin shade could contribute to this distinction. Arikawa et al, reported that size, shape, and amount of filler affected to the transmission of light on the materials.³¹ Regarding the amount of filler loads, Filtek Z350 XT showed opaquer even Filtek Z350 XT presented 78.5% by weight which was less than that

of Harmonize (81%wt) and Estelite Σ Quick (82%wt). However, this was inconsistent with the study of Suh et al, they pointed that the resin composite material would become opaquer when contained more filler loads.³² Differences of refractive index of fillers and resin matrix leads to and the scattering of light at the matrix/filler interface, resulting in the opacity of the materials.³³ Filtek Z350 XT contained 0.6-10 μ m zirconia/silica cluster in a resin matrix showed more opacity and thus demonstrated high masking ability performance.³⁴ In addition, the smaller the filler grain, the higher the translucency.³¹ Estelite Σ Quick consisted of 0.2 μ m spherical filler, and the color difference (ΔE_{T0}) of Estelite Σ Quick at 1 mm layering thickness was significantly higher than that of Filtek Z350 XT and Ceram X Duo. This was supported by the study of Perez et al, they studied 4 types of resin composite fillers: supra-nano spherical fill, nanofill, nano-hybrid, and micro-hybrid. They found that supra nano-spherical filler, contained in Estelite Σ Quick, had less light scattering than other types, leading to the high translucency. This might be resulted from the discrepancies of refractive indices between resin matrix and supra nano-spherical filler.³⁵ Moreover, translucency parameter of dentin and enamel shade of Estelite Σ Quick was higher than other nano-hybrid, and micro-hybrid resin composite.³⁶ Interestingly, types of monomer in the resin composite matrix might play a role in its optical properties. BisGMA-based resin composite had significantly higher translucency than UDMA and TEGDMA-based resin composite.³⁷ Further studies for chemical composition and microstructural analysis are required to confirm this speculation.

After thermocycling, the masking ability of all materials tended to be improved as observed by the decreased color difference value (ΔE_{T1}). ΔE_{T1} of Filtek Z350 XT and Ceram X Duo at all thicknesses and Harmonize at 1 mm thickness were less than 3.3 which was practically acceptable, consistent with the result at immediately restored. This acceptable masking ability and decreased ΔE_{T1} was consistent to the study of Lee et al.¹⁷ However, our result disagreed with the study of Perez et al. They found that after soaking in water for a year, the ΔE of 1.5 mm thickness resin composite was

increased.³⁸ This might be due to the different aging protocol and number of cycles, and different layering thickness preparation.

Concerning the color stability, this study found that all resin composites demonstrated a clinically acceptable color stability as shown by ΔE_{A1} of less than 3.3 after 5,000 cycles thermocycling. The color stability was influenced by the degradation of chemical compound, the oxidation of unreacted double-bonded carbon, accumulation of colorant, dehydration, water absorption, material's leakage, as well as the roughness of material surface.³⁹ Regarding the color change by water absorption, this was impacted by the filler size, resin matrix, as well as the filler ratio. Vichi et al found that distribution and size of filler affected to the color stability.⁴⁰ The resin composite containing larger filler tended to change in color compared to resin composite containing smaller filler after water aging. This was due to the larger filler, which had more filler boundary leading to the water absorption and light scattering. In this study, Filtek Z350 XT had the smallest filler size than others, so that it presented the highest color stability.

To mimic the long-term clinical usage, more than 5,000 cycles of thermocycling should be conducted in the future study to verify the significant change of color stability of resin composites. Moreover, there are other factors such as the pH change or beverage colorant, that might affect to the optical property of restoration and also the oral environment which might impact to the result, so that a further clinical study should be conducted.

As for the clinical application of this study, Filtek Z350 XT and Ceram X Duo with layering technique could mask the A4-discolored tooth at even 0.6 mm thickness. Harmonize could mask the discolored background at 1.0 mm. On the other hand, Estelite Σ Quick could not mask at every thickness. Importantly, an appropriate tooth reduction in order to obtain an optimal thickness of resin composite must be practiced in masking of discolored tooth background.

Conclusion

The masking ability of four resin composites with layering techniques on a discolored tooth at immediately restored and after thermocycling were significantly different. Harmonize, Ceram X Duo, and Estelite Σ Quick was likely to have higher masking ability when increasing the thickness except for Filtek Z350 XT. Thermocycling significantly affected to the masking ability of resin composites with layering techniques in some thicknesses. The color stability of all resin composites was significantly different, but clinically acceptable. Filtek Z350 XT showed the highest color stability amongst groups.

Clinical implication

Filtek Z350 XT and Ceram X Duo with layering technique could mask the A4-discolored tooth at even 0.6 mm thickness. Harmonize could mask the discolored background at 1.0 mm. On the other hand, Estelite Σ Quick could not mask at every thickness.

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Conflict of interest

None

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ความสามารถในการปิดสีและความคงทนของสี ของ เรซินคอมโพสิตที่ใช้เทคนิคการอุดแบบเป็นชั้น ๆ บนพื้นที่มีสีเข้ม ขณะบูรณะทันทีและภายหลังการเปลี่ยน อุณหภูมิร้อนเย็นแบบเป็นจังหวะ

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บทความวิจัย

บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อประเมินความสามารถในการปิดสีและความคงทนของสีของเรซินคอมโพสิตที่ใช้เทคนิคการอุดเป็นชั้น ๆ บนพื้นที่มีสีเข้มขณะบูรณะทันทีและภายหลังการเปลี่ยนแปลงอุณหภูมิร้อนเย็นแบบเป็นจังหวะ โดยการเตรียมชิ้นงานแผ่นวงกลมจากเรซินคอมโพสิตสีเนื้อฟันและสีเคลือบฟันจำนวน 340 ชิ้น จากเรซินคอมโพสิต 4 ยี่ห้อ คือ Filtek Z350 XT (3M-ESPE, USA), Harmonize (Kerr, USA), Ceram X Duo (Dentsply, Germany) และ Estelite Σ Quick (Tokuyama, Japan) โดยทำการอุดเป็นชั้น ๆ 5 รูปแบบ (n=17) คือ 0.3/0.3, 0.4/0.4, 0.5/0.3, 0.5/0.5 และ 0.7/0.3 ด้วยเรซินคอมโพสิตสีเนื้อฟันและสีเคลือบฟันตามลำดับ ทำการวัดความสามารถในการปิดสีผ่านค่าความแตกต่างของสีของเรซินคอมโพสิตที่อยู่บนพื้นหลังฟันธรรมชาติ A4 ขณะบูรณะทันที (ΔE_{T0}) และภายหลังการเปลี่ยนแปลงอุณหภูมิร้อนเย็นแบบเป็นจังหวะ (ΔE_{T1}) และประเมินความคงทนของสี (ΔE_{A1}) ของเรซินคอมโพสิตบนพื้นหลังเรซินคอมโพสิต A1 โดยพิจารณาจากค่า CIELab จากการใช้เครื่องวัดสีแบบสเปกโตรโฟโตมิเตอร์ โดยมีการนำชิ้นงานมาผ่านกระบวนการเปลี่ยนแปลงอุณหภูมิร้อนเย็นแบบเป็นจังหวะ (5 และ 55 องศาเซลเซียส) จำนวน 5,000 รอบ และวิเคราะห์ทางสถิติด้วยการทดสอบ Kruskal-Wallis และ Dunn's Bonferroni post hoc และการทดสอบ Wilcoxon matched-pairs signed rank test ในการหาความแตกต่างอย่างมีนัยสำคัญของความแตกต่างของสี ($p < 0.05$) ผลการศึกษาพบว่า ค่ามัธยฐานของความแตกต่างของสีของชิ้นงานที่บูรณะเป็นชั้น (ΔE_{T0} , ΔE_{T1} และ ΔE_{A1}) ของ Filtek Z350 XT คือ 1.52-2.00, 1.40-1.87, และ 0.94, Harmonize คือ 2.19-5.82, 2.34-5.65, และ 1.36, Ceram X Duo คือ 1.26-2.65, 2.13-2.45, และ 1.28 และ Estelite Σ Quick คือ 3.80-7.70, 4.07-8.10, และ 1.16 ตามลำดับ ค่า ΔE_{T0} และ ΔE_{T1} มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติระหว่างเรซินคอมโพสิตที่ใช้เทคนิคการอุดเป็นชั้น ๆ ที่แตกต่างกัน กระบวนการเปลี่ยนอุณหภูมิร้อนเย็นแบบเป็นจังหวะมีผลกระทบอย่างมีนัยสำคัญต่อความสามารถในการปิดสีในบางความหนา และยี่ห้อเรซินคอมโพสิตมีผลต่อความคงทนของสี (ΔE_{A1}) หลังการเปลี่ยนอุณหภูมิร้อนเย็นแบบเป็นจังหวะ ($p < 0.05$) โดยสรุปแล้วเรซินคอมโพสิตทุกยี่ห้อแสดงความสามารถในการปิดสีสูงขึ้นเมื่อเพิ่มความหนา ยกเว้น Filtek Z350 XT โดยความหนาขั้นต่ำ 0.6 มม. ของ Filtek Z350 XT และ Ceram X Duo และ 1.0 มม. ของ Harmonize สามารถปิดสีที่พื้นที่มีสีเข้มได้ ในขณะที่ Estelite Σ Quick ไม่สามารถปิดสีได้ในทุกความหนา ในแง่ของความคงทนของสีของเรซินคอมโพสิตนั้น ทุกยี่ห้ออยู่ในเกณฑ์ที่ยอมรับได้ทางคลินิก โดย Filtek Z350 XT แสดงความคงทนของสีสูงสุด

คำไรหรัส: เรซินคอมโพสิต/ เทคนิคการอุดแบบเป็นชั้น ๆ/ ความสามารถในการปิดสี/ ความคงทนของสี/ พื้นที่มีการเปลี่ยนสี

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