Comparison of Various Resin Composite Shades and Layering Technique with a Shade Guide

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ABSTRACT

Purpose: The purpose of this study was to compare the final shade of different shades of composites (enamel shades) over a white backing (WB) and black backing (BB), and a layering technique (enamel over dentin composite) with the corresponding Vita Classical Shade tabs (VST).

Materials and Methods: Composite disk specimens enamel ($N = 5$) shades B1, B2, A1, and A2, and dentin ($N = 1$) shades A1, A2, and A3 were made. The color of the VST B1, B2, A1, and A2, enamel shade disks, and layering composites of the same brand and different brands were assessed using a colorimeter over a WB and BB. The total color difference ($\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*_{ab})^2 + (\Delta b^*_{ab})^2]^{1/2}$) between the VST and the corresponding resin composite was calculated. The results were analyzed by one-way analysis of variance/Tukey's test ($p < 0.05$).

Results: Overall, the L^*, a^*, and b^* values of the enamel composite shades were significantly different from the corresponding VST. Only a few layered composites matched the L^*, a^*, and b^* of the keyed VST. Out of the 72 combinations, 20 (28%) resulted in ΔE^*_{ab} below the 3.3 clinically perceptible limit.

CLINICAL SIGNIFICANCE

Composite shades do not match well to the Vita shade guide tabs, even when the layering technique is used. As demonstrated in this study, only a few composites matched the corresponding Vita shade guide tabs.

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INTRODUCTION

Of today's restorative material options, resin composites have become widely used because of exceptional esthetics, conservative tooth preparations, and acceptable longevity for the treatment of anterior teeth. The objective of any esthetic restoration is to create a natural look that is pleasing to the patient while remaining functional. In order to achieve such an esthetic result, it is therefore the intention of the practitioner to

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simulate the appearance of natural tissue. The notion of the natural layering concept has allowed this goal to be reached by mimicking the normal anatomy of teeth.[1]

The natural layering concept attempts to replace the normal tissues in teeth, namely enamel and dentin, by restoring what was previously there. In the layering technique, a layer of more translucent material is applied over the opaque resin composite in order to create depth perception from within the restoration, thereby reducing the color coming only from the surface of the restoration.[2]

In order to achieve the desired characteristics of natural teeth, it should be the goal of the practitioner to make the thickness of the dentin and enamel layers of composite reproduce the anatomic thickness of that tooth prior to restoration.[3] The thickness of each layer applied needs to be adjusted based upon the location on the tooth. For example, for a maxillary central incisor, lateral incisor, and canine on the midcrown facial aspect of the tooth, the average thickness of the enamel is 1.0, 1.0, and 0.8 mm, respectively, whereas the average thickness of the dentin is 1.4, 1.1, and 2.0 mm, respectively.[4] To ensure an esthetic result in a composite restoration, not only is the thickness of composite important but also the shade selection is essential in matching the restoration to the patient's existing dentition and previously placed dental materials.

When selecting tooth shade, the middle site should be targeted because it best represents tooth color.[5] The incisal and cervical sites appear to be more affected by their surroundings.[5] The Vitapan Classical Shade Guide has become the gold standard in dentistry for selecting shades of composites. It is a good starting point for determining the composite shade. However, many problems arise in keying different brands of composite to one universal guide, and it has been demonstrated that improved standardization of resin composites needs to be addressed.[6]

There are a great variety of resin composite colors and brands. The A shade is statistically closest in average chromaticity to the average tooth.[7] Actually, the variations of a^* (color along the red-green axis) and b^* (color along the yellow-blue axis) values between A and B Vita shades do not seem to justify the use of distinct dentin colors, at least for direct composite restorative systems.[1] The C and D shades proved to be rarely observed in the natural dentition.[8–11] Therefore, several manufacturers only have A dentin shades, for example, Gradia, Miris, and Estelite, to name a few. In the present study, only A dentin shades were used for the dentin layer.

Various studies have compared the compatibility of resin composites of identical shade designation and concluded that poor color compatibility often exists between pairs of shades .[6,12–16] In fact, Paravina and colleagues[6] concluded that 75% of the shade pairs they tested showed a shade "mismatch." Kamishima and colleagues[2] evaluated the translucency of composites at various thicknesses and found that translucency increased exponentially as the thickness was reduced, no matter what shade was used. They concluded that the translucency of the enamel shades and the opacity of the dentin shades greatly affect the resulting esthetics of the restoration. Furthermore, the color is influenced not only by the optical properties of the covering layer but also by the color and optical properties of the underlying layer.[17]

The ability to standardize composite shades from different manufacturers to a single shade guide still requires further exploration. The literature is also lacking in an evaluation of the adequate thickness of the enamel and dentin shades when conducting the layering technique using different backgrounds, and how this relates to shade matching.

TABLE 1. RESIN COMPOSITES EVALUATED.

Resin composite	Code	Manufacturer	Shade-lot no.
Filtek Supreme Plus	FS	3M ESPE, St. Paul, MN, USA	B1E-5028 B2E-5028 A1E-5028 A2E-5028 A1D-5028 A2D-5028 A3D-5028
Premise	P	Kerr Corporation, Orange, CA, USA	B1E-2719074 B2E-451876 A1E-2716178 A2E-451867 A2D-461247 A3D-458192
Estelite Sigma	ES	Tokuyama Dental, Tokyo, Japan	B1E-W655 B2E-W609 A1E-E511B A2E-E427 A1D-W756B A2D-W861 A3D-W958B

The purpose of this study was to compare the final shade of different shades of composites (enamel shades) over a white backing (WB) and black backing (BB), and a layering technique (enamel over dentin composite) with the corresponding Vita Classical Shade tabs (VST).

The null hypothesis to be tested was that there would be no difference in color matching to the corresponding Vita shade tab among the composite shade combinations regardless of the backing used.

MATERIALS AND METHODS

Disk-shaped specimens (8 mm in diameter, 1-mm thick for enamel shades and 1.5-mm thick for dentin shades) were made by packing uncured composite into a polytetrafluoroethylene ring mold. Molds were placed over transparent Mylar strips that were already positioned over a glass microscope slide. After application and sculpting of resin composite, another Mylar strip and glass slide were placed over each surface of the uncured composite to eliminate oxygen inhibition. A 0.5-kg load was placed on the mold for 30 seconds to extrude the excess material. The specimens were then light-polymerized for 40 seconds using the LED Demetron 1 (Kerr Corporation, Orange, CA, USA). The light output was always measured after 10 specimens were light-polymerized using a radiometer (Model 100, Kerr Demetron, Danbury, CT, USA), and the irradiance always ranged between 700 and 760 mW/cm^2.

Three commercial resin composites were evaluated: Filtek Supreme Plus (FS; 3M ESPE, St. Paul, MN, USA), Premise (P; Kerr Corporation), and Estelite Sigma (ES; Tokuyama Dental, Tokyo, Japan) (Table 1). The enamel shade of P is called body, and FS has both enamel and body (more opaque than enamel shade). The enamel shade of P is called body, and FS has both enamel and body (more opaque than enamel shade) shades. Only the enamel shades were evaluated; the FS body shade was not included in this study. The dentin shades might be called dentin or opaque. To simplify the naming convention, the composites evaluated were called "enamel shades" (E) and "dentin shades" (D).

Enamel shade specimens ($N = 5$) were made as disks, 8 mm in diameter and 1-mm thick. The 1-mm thickness was chosen because that is the average thickness of the enamel on the midcrown of the anterior maxillary teeth.[4] Four enamel shades were evaluated: B1, B2, A1, and A2. Dentin shade specimens ($N = 1$) were made as disks, 8 mm in diameter and

TABLE 2. ENAMEL AND DENTIN SHADES THAT WERE USED FOR THE LAYERING TECHNIQUE AND THE CORRESPONDING VITA SHADE TAB TO WHICH THEY WERE COMPARED.

Composite enamel shade (E)	Composite dentin shade (D)	Vita shade tab
B1	A1/A2 for P	B1
B2	A2	B2
A1	A2	A1
A2	A3	A2

1.5-mm thick, using cylindrical molds. The 1.5-mm thickness was chosen because that is the average thickness of the dentin on the mid-crown of the anterior maxillary teeth.[4] Three dentin shade disks, A1, A2, and A3, were fabricated to be placed under the enamel shade disks with the purpose of simulating the layering technique. P was the only composite that did not have an A1 dentin shade. Therefore, for P, the A2 dentin shade was used when the A1 of the other two brands was used.

The color of enamel composite shade disks was taken by one trained person using a colorimeter (CR-221, Minolta, Ramsey, NJ, USA) with a diameter tip of 4 mm. The tip of the colorimeter was placed in the middle of each specimen. Three measurements were taken of each specimen over a WB ($L^* = 93.56$, $a^* = -1.97$, and $b^* = 3.53$) and over a BB ($L^* = 29.38$, $a^* = -0.93$, and $b^* = 0.07$). For the layered composite, an enamel disk was placed over a dentin disk to replicate the layering technique (Table 2). The color measurements of the specimens were taken of the layering technique using composites of the same brand as well as the combination of shades of composites of different brands. Prior to starting this study, we did a pilot study to evaluate if there was a difference between layering enamel and dentin composites, and stacking enamel and dentin composite disks. There was no significant difference in color, therefore, for the simplicity of the study, we decided to use the composite disks.

A new shade guide purchased in 2007 was used for this study. The metal tab holders were removed, and the lingual part of the tabs was slightly ground flat. A circular area (d = 0.5 cm) on the middle of the labial surface of the tab, excluding the cervical and incisal portions, was measured. Three color measurements of B1, B2, A1, and A2 VST (Vita Zahnfabrik, Bad Sackingen, Germany) were taken using the colorimeter over a WB and BB.

The colorimeter was calibrated using the white calibration tile provided by the manufacturer. The colorimeter measures the color of the teeth based on the CIE (Commission Internationale de l'Eclairage) color space system[18] in which L^* measures the value, a^* measures the color along the red-green axis, and b^* measures the color along the yellow-blue axis. ΔE^* is the total color difference or the distance between two colors (CIE). The total color difference between the VST and the corresponding resin composite was calculated using the formula: $\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*_{ab})^2 + (\Delta b^*_{ab})^2]^{1/2}$.[19] A value of ΔE^*_{ab} greater than 3.3 is generally considered the clinically perceptible limit.[20]

Statistical Analysis

The means and standard deviations were determined for L^*, a^*, and b^*values, and ΔE^*_{ab} values of the color difference between the composite disks and the corresponding VST. The results were analyzed by one-way analysis of variance and Tukey's test ($\alpha \leq 0.05$). Only the color of the enamel shades was compared with the corresponding VST, and then the color of the layered composite of the same brand and the combination of layered composites of different brands was compared with the corresponding tab for each composite, over both WB and BB.

RESULTS

The mean absolute color coordinate values and standard deviations of the Vita shade tabs evaluated are presented in Table 3 (there was no difference between the color measurements over the WB or BB).

The ΔE^*_{ab} comparing the color difference between the VST and the enamel composite, layering technique of the same brand and layering technique of various brands measured over both WB and BB are presented in Tables 4 through 6.

The L^*, a^*, and b^* values of all enamel composite shades evaluated over the WB and BB were significantly different from VST ($p < 0.001$), except for A2E of the ES a^* value ($p = 0.76$) over WB. The range of L^* values was 63.63 to 68.40 over WB, and 50.47 to 58.95 over BB; the range of a^* values was –2.28 to 0.34 over WB, and –3.11 to –1.1 over BB; and the range of b^* values was 15.39 to 3.76 over WB, and –7.91 to 6.1 over BB. The ΔE^*_{ab} of all enamel composites was greater than the clinically perceptible limit of 3.3, except for B1E of P over BB (Table 4).

For B1E in combination with A1D of the same brand, all L^*, a^*, and b^* values were significantly different from B1 VST values ($p < 0.001$), except for the a^* value of P ($p = 0.41$) over WB. The ΔE^*_{ab} values of the layered composites were greater than 3.3, except for ES over both backings (Table 5, Figure 1). The range of L^* values was 58.31 to 62.47 over WB, and 56.78 to 61.59 over BB; the range of a^* values was –2.22 to –0.67 over WB, and –2.37 to –0.94 over BB; and the range of b^* values was –0.56 to 6.47 over WB, and –1.45 to 5.70 over BB.

For B1E in combination with A1D of different brands, only the L^* values of FS/ES over WB ($p = 0.08$), and FS/P over BB ($p = 0.79$); the a^* value of FS/ES over BB ($p = 1.0$); the b^* values of ES/P over WB ($p = 0.543$), and P/ES over BB ($p = 0.236$) were not significantly different from B1 VST. The ΔE^*_{ab} values of the layered composites were greater than 3.3, except for ES/P, and ES/FS over both backings (Table 6, Figure 1). The range of L^* values was 57.41

TABLE 3. L^*, a^*, AND b^* AND SD OF VITA CLASSICAL SHADE GUIDE TABS.

Shade	L^*	SD L^*	a^*	SD a^*	b^*	SD b^*
B1	56.94	0.02	–1.46	0.01	5.05	0.01
B2	53.36	0.01	–0.84	0.01	7.56	0.01
A1	55.75	0.12	–0.78	0.11	6.07	0.02
A2	54.21	0.14	–0.15	0.03	9.16	0.04

TABLE 4. ΔE^*_{ab} OF THE VITA CLASSICAL SHADE TABS AND THE CORRESPONDING ENAMEL RESIN COMPOSITE EVALUATED USING THE WB AND BB.

Shade	Brand	ΔE^*_{ab} over WB	ΔE^*_{ab} over BB
B1E	FS	9.21	13.72
B1E	P	11.99	2.81*
B1E	ES	10.15	5.69
B2E	FS	12.16	6.81
B2E	P	15.51	6.67
B2E	ES	13.26	3.4
A1E	FS	10.72	8.92
A1E	P	11.98	4.22
A1E	ES	10.32	6.06
A2E	FS	10.06	8.66
A2E	P	11.89	5.15
A2E	ES	9.45	8.06

BB = black backing; ES = Estelite Sigma; FS = Filtek Supreme; P = Premise; WB = white backing.

The value with the asterisk is below 3.3.

TABLE 5. ΔE^*_{ab} OF THE VITA CLASSICAL SHADE TABS AND THE CORRESPONDING LAYERED COMPOSITE OF THE SAME BRAND EVALUATED USING THE WB AND BB.

Shade	Brand	Shade	ΔE^*_{ab} over WB	ΔE^*_{ab} over BB
B1E	FS	A1D	6.07	6.75
B1E	P	A2D	5.71	4.74
B1E	ES	A1D	1.76*	1.71*
B2E	FS	A2D	4.59	4.24
B2E	P	A2D	9.46	8.58
B2E	ES	A2D	3.70	2.45*
A1E	FS	A2D	3.33*	4.33
A1E	P	A2D	4.92	4.40
A1E	ES	A2D	2.68*	2.83*
A2E	FS	A3D	2.73*	3.70
A2E	P	A3D	4.30	4.09
A2E	ES	A3D	3.20*	3.71

BB = black backing; ES = Estelite Sigma; FS = Filtek Supreme; P = Premise; WB = white backing.

Values with the asterisks are below 3.3.

to 63 over WB, and 56.27 to 62.54 over BB; the range of a^* values was –2.11 to –0.33 over WB, and –2.36 to –1.04 over BB; and the range of b^* values was –2.22 to –6.82 over WB, and –4.19 to 6.47 over BB.

For B2E in combination with A2D of the same brand, all L^*, a^*, and b^* values were significantly different from B2 VST over both backings ($p < 0.001$), except the L^* value of ES. The ΔE^*_{ab} of the layered composites was greater than 3.3 for all composites, except for ES over the BB (Table 5, Figure 2). The range of L^* values was 54.31 to 61.86 over WB, and 55.96 to 62.81 over BB; the range of a^* values was –2.5 to –1.39 over WB, and –1.98 to –0.72 over BB; and the range of b^* values was 5.62 to 9.03 over WB, and 7.06 to 9.94 over BB.

For B2E in combination with A2D of different brands, only the a^* value of FS/ES over the WB ($p = 1.0$) and the b^* value of P/FS over the BB ($p = 1.0$) were not significantly different from B2 VST. The range of L^* values was 56.25 to 63.21 over WB, and 55.32 to 62.33 over BB; the range of a^* values was –1.86 to –0.65 over WB, and –2.30 to –1.38 over BB; and the range of b^* values was 5.78 to 11.11 over WB, and 3.88 to 10.94 over BB.

For A1E in combination with A2D of the same brand, all L^*, a^*, and b^* values were significantly different from A1 VST ($p < 0.001$), except for the L^* ES value ($p = 0.77$) and the b^* P value over the BB ($p = 0.136$). The ΔE^*_{ab} values of the layered composites were greater than 3.3, except for ES over both backings (Table 5, Figure 3). The range of L^* values was 57.48 to 60.65 over WB, and 56.03 to 60 over BB; the range of a^* values was –1.06 to –0.40 over WB, and –1.66 to –1.08 over BB; and the range of b^* values was 3.8 to 5.8 over WB, and 2.58 to 5.02 over BB.

For A1E in combination with A2D of different brands, only the L^* value of FS/ES over the BB ($p = 0.82$) and the b^* value of P/FS over the WB ($p = 0.938$) were not significantly different from A1 VST. The ΔE^*_{ab} values of the layered composites were greater than 3.3, except for ES/FS, and ES/P over both backings (Table 6, Figure 3). The range of L^* values was 57.35 to 60.67 over WB, and 56.18 to 60.48 over BB; the range of a^* values was –1.09 to –0.46 over WB, and –1.68 to –1.06 over BB; and the range of b^* values was 2.78 to 6.16 over WB, and 0.7 to 5.44 over BB.

For A2E in combination with A3D of the same brand, all L^*, a^*, and b^* values were significantly different from A2 VST ($p < 0.001$), except for the L^* value of ES over the BB ($p = 0.163$). The ΔE^*_{ab} of

TABLE 6. ΔE^*_{ab} OF THE VISTA CLASSICAL SHADE TABS AND THE CORRESPONDING LAYERED COMPOSITE OF DIFFERENT BRANDS EVALUATED USING THE WB AND BB.

Shade	Brand	Shade	Brand	ΔE^*_{ab} over WB	ΔE^*_{ab} over BB
B1E	FS	A2D	P	6.62	8.02
B1E	FS	A1D	ES	7.3	9.27
B1E	P	A1D	FS	6.31	5.82
B1E	P	A1D	ES	5.01	4.22
B1E	ES	A1D	FS	2.80*	2.28*
B1E	ES	A2D	P	1.84*	0.95*
B2E	FS	A2D	P	4.22	4.07
B2E	FS	A2D	ES	3.4	4.24
B2E	P	A2D	FS	9.90	9.03
B2E	P	A2D	ES	8.59	7.94
B2E	ES	A2D	FS	5.19	4.59
B2E	ES	A2D	P	4.43	3.82
A1E	FS	A2D	P	3.4	4.57
A1E	FS	A2D	ES	3.66	5.46
A1E	P	A2D	FS	4.92	4.78
A1E	P	A2D	ES	4.47	3.84
A1E	ES	A2D	FS	2.82*	2.42*
A1E	ES	A2D	P	2.62*	2.31*
A2E	FS	A3D	P	3.15*	4.32
A2E	FS	A3D	ES	2.86*	4.58
A2E	P	A3D	FS	4.39	4.20
A2E	P	A3D	ES	4.32	3.9
A2E	ES	A3D	FS	2.93*	2.75*
A2E	ES	A3D	P	3.4	3.5

BB = black backing; ES = Estelite Sigma; FS = Filtek Supreme; P = Premise; WB = white backing.

Values with the asterisks are below 3.3.

layered composites was higher than 3.3 for all the composites evaluated over both backings (Table 5). The range of L^* values was 55.29 to 58.35 over WB, and 53.96 to 57.70 over BB; the range of a^* values was –0.57 to 0.16 over WB, and –1.08 to –0.67 over BB; and the range of b^* values was 6.16 to 7.95 over WB, and 5.5 to 7.08 over BB.

For A2E in combination with A3D of different brands, all L^*, a^*, and b^* values were significantly different from A2 VST ($p < 0.001$), except for the a^* value of FS/ES ($p = 0.9$) and ES/FS ($p = 0.58$) over the WB, and the L^* value of FS/ES ($p = 0.305$) over BB. The ΔE^*_{ab} of layered composites was lower than 3.3 for ES/FS over both backings (Table 6, Figure 4). The range of L^* values was 55.11 to 58.40 over WB, and 54.24 to 58.13 over BB; the range of a^* values was –0.060 to 0.27 over WB, and –1.15 to 0.63 over BB; and the range of b^* values was 6.29 to 8.43 over WB, and 4.68 to 6.84 over BB.

DISCUSSION

There was a poor color match when comparing the composite enamel shades of all brands with the VST with no dentin backing, especially with the WB. The range of ΔE^*_{ab} values of the enamel composites evaluated over the WB was 9.21 to 15.51, and over the BB was 2.81 to 13.72 (Table 4). Therefore, the null hypothesis was rejected when the shades were measured over the WB and accepted for only one enamel shade, P B1E, over the BB. Another study evaluated resin composites and compared enamel and dentin shades with the VST over a WB and also found that the great majority of the composites did not match the VST, with the range of ΔE^*_{ab} values being 0.9 to 12.8.[16] The results of both studies are most likely because of the small thickness of the enamel specimen evaluated. Thin composites contain less filler particles, therefore more background light is reflected, increasing the impact of the background shade.[21] The background color is known to affect the overall color of a composite resin,[21–25] even at a thickness of 2 mm.[25,26] In

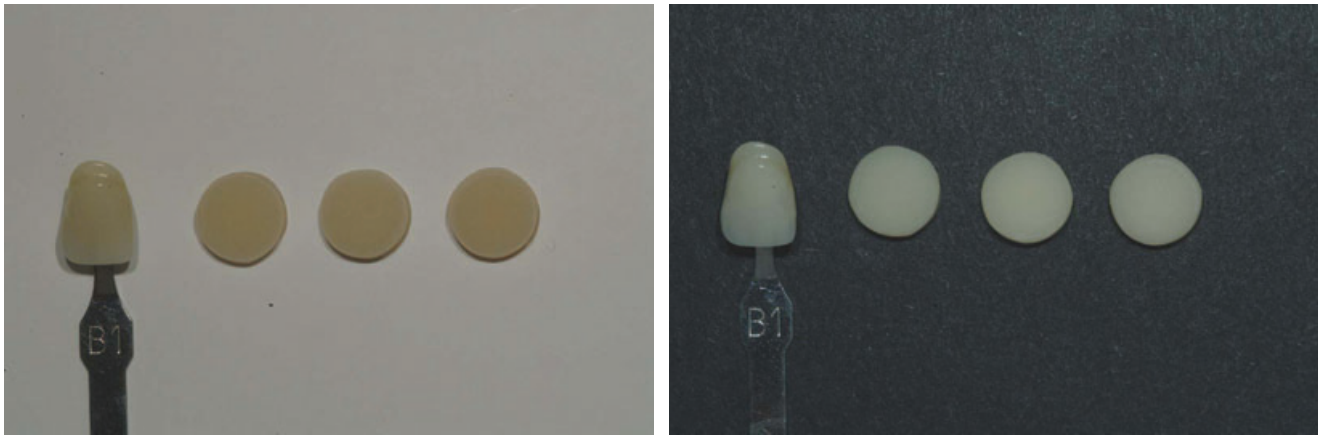

Figure 1. Composite specimens that showed ΔE^*_{ab} values below 3.3 compared with the B1 VST over white (left) and black (right) backings. From left to right: ES/ES, ES/FS, and ES/P. ES = Estelite Sigma; FS = Filtek Supreme; P = Premise.

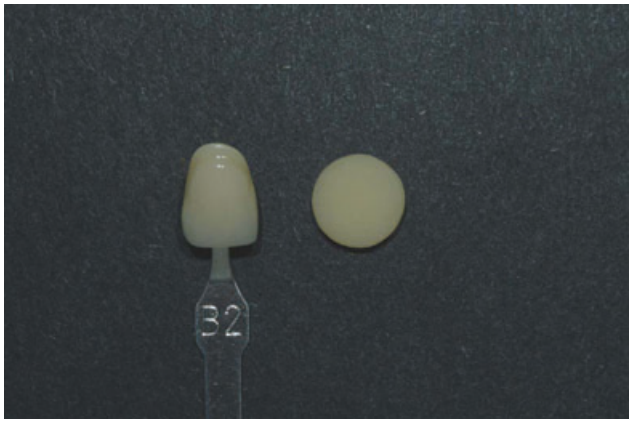

Figure 2. Composite specimen that showed an ΔE^*_{ab} value below 3.3 compared with the B2 VST over BB: ES/ES. ES = Estelite Sigma.

order to eliminate any doubt that the backing was influencing the overall shade, we measured the layering technique over both WB and BB.

According to previous studies, the same shade designation of various composite brands showed poor color compatibility. Although it was not the purpose of this study, a great color difference was obvious among the composite brands evaluated. Overall, for all enamel composites evaluated for the same Vita shade designation, the L^* values were very similar among them, but the a^* and b^* values were quite different, making the overall color vary considerably. These differences between composite and corresponding VST make shade selection challenging for clinicians, and they should be aware of the lack of compatibility of brands with identical shade designation when placing resin composites.

When the dentin shades were layered by the enamel shades to simulate the layering technique, some of the composites had a closer match to the VST, thus allowing us to accept the null hypothesis. Upon layering composite of the same brands, the L^* values of the composites evaluated were all lighter regardless of the background used. The a^* values of FS tended to be more green, and the b^* values tended to be more blue than the a^* and b^* values of the corresponding VST. These findings were similar to ES, except that ES presented L^* values very similar

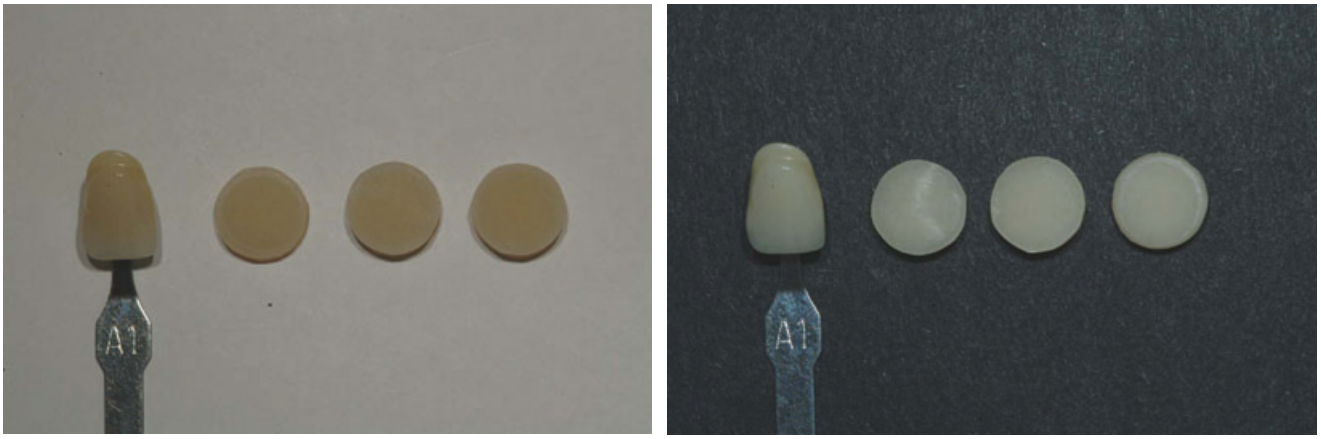

Figure 3. Composite specimens that showed ΔE^*_{ab} values below 3.3 compared with the A1 VST over white (left) and black (right) backings. From left to right: ES/E and ES/D, ES/FS, and ES/P. ES = Estelite Sigma; FS = Filtek Supreme; P = Premise.

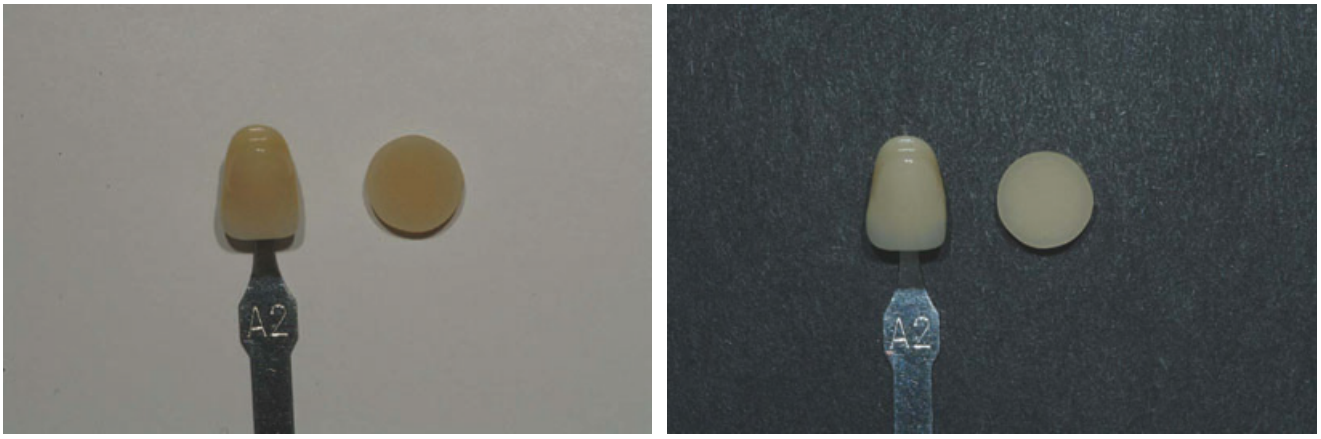

Figure 4. Composite specimen that showed an ΔE^*_{ab} value below 3.3 compared with the A2 VST over white (left) and black (right) backings: ES/FS. ES = Estelite Sigma; FS = Filtek Supreme.

to the VST, especially against the BB. In contrast, the B1 and B2 b^* values of P were more yellow, and the a^* values of A1 and A2 were more red than the VST.

The enamel composite shades were layered over the dentin shades with the same brand as well as with mixed brands. The layering technique using the same brand showed that ES presents similar shades to the VST for the four shades evaluated, and FS enamel A2 layered over dentin A3 presents a similar shade to the A2 VST. When mixing brands, it was shown that different enamel shade brands can be mixed with different dentin shade brands and produce similar shades to the corresponding VST, especially if the enamel shades used are from ES (Tables 5 and 6).

Only a few composites layered produced a good match to the corresponding VST, and some results were different depending on the backing, thus leading to partial acceptance of the null hypothesis.

The best matches, ΔE^*_{ab} closer to zero, were for B1 ES/E and P/D ($\Delta E^*_{ab} = 0.95$) over the BB, for B2 ES/ES ($\Delta E^*_{ab} = 2.45$) over the BB, for A1 ES/P ($\Delta E^*_{ab} = 2.31$) over the BB, and for A2 FS/FS ($\Delta E^*_{ab} = 2.73$) over the WB. Interestingly, though, the combination of ES enamel with various dentin shade brands matched the corresponding VST when measured over either WB or BB. For B1 and A1, the combination of ES/E to any A1D evaluated matched the VST. For A2, the combination of ES/E to ES/D and FS/D matched the VST. For B2, the only combination that matched the VST was ES/E and ES/D over the BB. B2 was the hardest shade to match to the VST.

For the 4 VST, 4 composite enamel shades, 3 dentin shades, and 2 backings, 72 combinations were evaluated. Out of the 72 combinations, 20 (28%) presented ΔE^*_{ab} below the clinically perceptible limit of 3.3 (Tables 5 and 6). Out of the 20 combinations, 16 (80%) were the ES enamel composite layered over any dentin composite shade brand, and the other 4 combinations (20%) were the FS enamel shade layered over any other dentin shade brands. These results showed that some composites are truly keyed to the Classical Vita shade guide. Therefore, when trying to reproduce the natural tooth color, it makes sense to choose the tooth color from the middle of the tooth, and then correspond it to selected enamel composites and layer over A dentin shades when using these composites. Apart from that, it is important to mention that the range of shades in shade guides is not consistent with natural teeth, and dental shade guides typically contain a limited selection of colors compared with those found in human teeth.[27] Thus, often, the clinician must define tooth color by approximation to the nearest shade of the shade guide.

One of the limitations of this study is the difference in geometry of the composite specimens and the shade guide tabs. Although the shade guide tabs are curved resembling the central incisor anatomy and the tabs are flat, care was taken to take the color measurement from the flattest middle area of the tab. Another limitation is that the enamel and dentin shade composites were not layered as they usually are during a restorative procedure. The enamel disk was placed over the dentin disk simulating the layering technique for the simplicity of the study. In the future, the layering technique should be evaluated with optical unity between the layers. Only a few shades, the most used ones, and only three composite brands were evaluated. In the future, more VST and composite brands should be studied using the layering technique. Another limitation is that only one shade guide was used, the most popular one. In the future, other shade guides should be evaluated. Moreover, shade guides are not a perfect standard in that they do not cover the entire color range of natural teeth, they have an uneven distribution in color space, they have suboptimal tab arrangement, and they vary between batches.[11,28–34] Nonetheless, the shade guide is still the gold standard and is a good starting point for determining the composite shade for the composite layering technique.

CONCLUSION

Within the limitations of this study, composite shades do not match well to the Vita shade guide, even when a layering technique is used. Only a few composites, ES enamel layered over ES dentin shades, and ES enamel layered over FS and P dentin shades, produced ΔE^*_{ab} below the perceptible limit when compared with the corresponding VST.

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