Original Article

Color match of single-shade restorations after professional dental bleaching: An *in vitro* study

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Abstract

Background: Restorative dentistry aims to reproduce natural tooth shades through resin composites that must be layered to obtain colors, opacities, and translucencies, and therefore, clinical success is operator skill dependent.

Aims: The purpose of this study is to evaluate the color shift of single-shade composite restorations before and after dental bleaching.

Materials and Methods: Eighty human extracted posterior teeth were restored with four single-shade composites (Omnichroma OM; Clearfil Majesty ES-2 Universal CL; Essentia Universal ES; Venus Diamond One VE) (n = 20 each). Standardized V class cavities were prepared on buccal side. VITA Easyshade V spectrophotometer was used to register VITA color and color coordinates 24 h before (T_0), 24 h after (T_1), and 1 week after (T_2) dental bleaching (Opalescence Boost PF 40%). Color differences (ΔE_{ab}) and (ΔWI_D) were calculated and subjected to statistical analysis.

Statistical Analysis: Categorical variables were analyzed using Pearson Chi-square, and data from color coordinates were analyzed using one-way analysis of variance and Tukey's multiple comparison test with Bonferroni correction. Paired t-tests were performed to compare continuous measures between groups and treatment time.

Results: Instrumental evaluations revealed statistically significant differences between materials ($P < 0.05$) with lower values for ES and VE samples followed by CL and OM at T_0 and T_1. At T_2, OM and CL ΔE_{ab} values decrease getting closer to ES and VE.

Conclusion: Single-shade composites seem to match with the surrounding bleached tooth.

Keywords: Bleaching; color match; filling materials; restorative dentistry; single-shade composites

INTRODUCTION

Optical properties of natural teeth are the result of enamel and dentin overlapping and their interaction with the light and the surrounding tissues.[1]

One of the biggest challenges in restorative dentistry is to reproduce natural tooth shades using resin composites[2] that must be layered through several increments of different colors, opacities, and translucencies.[3] Therefore, clinical success is still operator skill dependent, although modern composites seem to be able to assimilate the color of the surrounding structures through a phenomenon named blending effect (BE).[4]

In dentistry, the BE concerns the correlation between teeth and dental materials, and it is expressed by a smaller color diversity when viewed together, rather than observed individually: or rather, the detected color of an area changes toward the color of the surroundings. The BE helps the clinician's work since it attenuates or counteracts color

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mismatches, or/and therefore the lack of suitable shade in selected materials for restorative dentistry.[1]

When light enlightens through composites, it disperses at the surface of the filler particles and spreads in several directions. This light conveyance through composite consists of a straight-line dissemination,[5] and the composite filler particles could condition this light conveyance features. Moreover, the restoration BE could be conditioned by the light diffusing refraction and scattering through the composite. Therefore, an assessment of light conveyance of composite having several filler morphologies is essential to foretell shade matching.[5]

Recently, single-shade composites have been developed to achieve, through a unique color mass, a color match with all 16 shades of the VITA scale, and with all color shades of natural teeth. This has been possible due to modified optical properties that let single-shade composites be able to acquire the surrounding tooth color.[6] These new composites seem to be very effective in reducing in-chair clinical timing by minimizing the time spent on shade selection.[7,8]

In esthetic dentistry, color differences between tooth and restoration can be accurately evaluated through an instrumental analysis using an intraoral spectrophotometer. This device can detect VITA scale values and CIELAB (L*, a*, and b*) coordinates: L* stands for lightness, represented on a scale of 0 (black) to 100 (white); a* represents the hue and chroma values on the red (+) and green (−) axis; b* instead on the yellow (+) and blue (−) one.[9] Data obtained from the spectrophotometer can also be used to calculate the color difference between tooth and composite, through the ΔE_{ab} formula developed in 1976 as CIELAB color difference formula.[10]

One of the most common esthetic issues in the anterior areas can arise in case of need of professional tooth bleaching. In this clinical situation, previously performed resin restorations are not able to shift their shade following the whitening of the tooth, and often the replacement of the composites is needed.[11]

According to the authors' best knowledge, few previous studies focused on the color match evaluation between several single-shade resins and the surrounding tooth, prior and after dental whitening procedures.[12-14] None of these studies however evaluated the level of white of the restorations using a recently introduced CIELAB-based whiteness index for dentistry (WI_D).[15]

Accordingly, the purpose of this study was to test *in vitro* the color correspondence of 4 single-shade composite resins with extracted teeth in which they have been applied, and to determine the correspondence of WI_D between the tooth and the respective restoration after professional bleaching.

The null hypothesis tested were that (1) there is no significant color difference between the 4 tested single-shade composites and teeth shades and (2) that there is no correspondence between WI_D values of these resins and teeth after whitening procedures.

MATERIALS AND METHODS

Four different single-shade composites were selected to restore eighty extracted sound posterior teeth: Omnichroma (Tokuyama Dental, Tokyo, Japan) (OM), Venus Diamond One (Kulzer, Hanau, Germany) (VE), Clearfil Majesty ES-2 Universal (Kuraray Medical Inc., Tokyo, Japan) (CL), and Essentia Universal (GC Corporation, Tokyo, Japan) (ES).

Sound extracted teeth were selected according to the University of Bologna Ethical Committee approval (protocol N°:71/2019/OSS/AUSLBO). Teeth were free of restorations, decays, and endodontic treatment. Following a previously published research protocol,[8] teeth were randomly divided into 4 groups, 20 teeth in each group ($n = 20$), and were stored in distilled H_2O at 37°C in single sealable compartments for 24 h.[16,17]

Two mm above the cementoenamel junction, on the vestibular aspect of each tooth, a standardized class V cavity (2 mm in high and depth, and 4 mm width) was performed. A round-shaped diamond bur (#6801314029, Komet Dental, Lemgo, Germany) was used under water cooling to create the cavity and a finishing bur (#8390314016, Komet Dental, Lemgo, Germany) was used to bevel cavity margins, both replaced every 2 samples.[18]

Selective etching was performed on enamel with 37% orthophosphoric acid for 30 s. The acid was rinsed, and the surface was dried, then adhesive procedures were carried on according to the manufacturer. Each composite was used together with its corresponding universal adhesive system: Universal Bond (Tokuyama), iBond Universal (Kulzer), Clearfil Universal (Kuraray) and G2 Bond Universal (GC). The Universal adhesive system was then gently dried and cured for 10 s at 1400 mW/cm2 with a blue-led light-curing device (Mectron Starlight Pro, Italy). Each cavity was finally filled through a single increment of the correspondent one-shade composite resin and polymerized for 40 s with the previously used led light-curing unit, placed in contact with the specimens.

After polymerization, the restorations were polished with a dedicated finishing/polishing system (Clearfil Twist DIA,

Kuraray Medical Inc.), using a slow-speed handpiece at 4000 rpm for 30 s per step, and were stored in distilled H_2O at 37°C for 24 h.[16,17]

Bleaching procedures

Specimens were treated through a 40% hydrogen peroxide bleaching gel (Opalescence Boost PF 40%, Ultradent, South Jordan, USA). Teeth were fixed on a wax plate before the application of the bleaching product,[13] which was placed to cover the entire surface of the tooth other than the restoration, to not alter the mechanical and physical resin properties. According to the manufacturer, two consecutive bleaching sessions, 20 min each,[19] were performed for every tooth.

After both applications, the bleaching agent was gently removed using gauze drenched in distilled H_2O and then the specimen surfaces were washed out and dried with ab-sorbent paper. They were not air-dried to avoid any system that could cause dehydration.[13]

Instrumental color measurements

Using an intraoral spectrophotometer (VITA Easyshade V, VITA Zahnfabrik, Bad Sackingen, Germany), the following tooth-related color variables were evaluated by a single dental operator with standardized D65 light illumination: VITA color, CIELAB color coordinates (L^*: lightness, a^*: green-red coordinate and b^*: blue-yellow coordinate), chroma (C^*), and hue (h°). A neutral grey paper was used as a background during measurements,[9,13] and the device was calibrated after every three measurements.[9]

As indicated by the manufacturer, the tip of the device was used perpendicularly in contact with the surfaces, and the adequate exposure time was given by the spectrophotometer.

All values were measured on the tooth, 1 mm away from the margin of the restoration, and at the center of the restoration.[16]

Color differences were calculated using the following CIELAB formula and expressed as Δ_{ab}:[5] $\Delta E_{ab} = ([\Delta L^*]^2 + [\Delta a^*]^2 + [\Delta b^*]^2)^{1/2}$, where: $\Delta L^* = L^*rest - L^*tooth$; $\Delta a^* = a^*rest - a^*tooth$; $\Delta b^* = b^*rest - b^*tooth$ (rest = restoration; tooth = treated tooth).

Color match assessments were evaluated before (T_0), after 24 h (T_1), and after 1 week (T_2) of the whitening procedures.

The whiteness index (WI_D) was calculated using the following equation:[15] $WI_D = 0.511\ L^* - 2.324a^* - 1.100b^*$.

Differences in whiteness index (ΔWI_D) were finally evaluated with the whiteness 50%:50% perceptibility (WPT = 0.61 ΔWI_D units) and 50%:50% acceptability (WAT = 2.90 ΔWI_D units) thresholds for lay people, and the whiteness 50%:50% perceptibility (WPT = 0.44 ΔWI_D units) and 50%:50% acceptability (WAT = 2.15 ΔWI_D units) thresholds for dentist population.[15]

Statistical analysis

Statistical analysis was performed using STATA program version 17 (StataCorp LP 4905 Lakeway Drive College Station, Texas 77845 USA). Means, standard deviations, counts, and percentages were used to summarize the data. Categorical variables were analyzed using Pearson Chi-square. Since the normality and homogeneity of variance were satisfied by Levene's test ($P < 0.05$), data from color coordinates (CIE L^*, a^*, b^*, C^*, and h°) were statistically analyzed using one-way analysis of variance (one-way ANOVA) and Tukey's multiple comparison test with Bonferroni correction. One-way ANOVA was used to compare the effects of color differences ΔE_{ab} value among the materials. Paired *t*-tests were performed to compare continuous measures between groups and treatment time. $P \leq 0.05$ was considered statistically significant. The statistician was blinded to the groups.

RESULTS

Mean color differences (ΔE_{ab}) and standard deviations (SDs) between the restored composite and the tooth at baseline (T_0), 24 h (T_1), and 1 week (T_2) after whitening procedures for each resin are presented in Table 1.

A significant difference between materials ($P < 0.05$) was revealed by the statistical analysis. Statistically significant differences were found at T_0 between OM and VE ($P = 0.001$), OM and ES ($P < 0.001$), CL and VE ($P < 0.001$), Cl and ES ($P < 0.001$); at T_1 between OM and VE ($P < 0.005$), VE and ES ($P = 0.023$), VE and CL ($P < 0.001$); any statistically significant differences did not show up among groups at T_2.

Statistical analysis showed significant differences between OM T_0 and OM T_1 ($P < 0.001$), and OM T_0 and OM T_2 ($P < 0.001$); VE T_0 and VE T_1 ($P = 0.003$), and VE T_0 and VE T_2 ($P = 0.003$); ES T_0 and ES T_2 ($P < 0.002$), and ES T_1 and ES T_2 ($P = 0.016$); CL T_0 and CL T_1 ($P < 0.001$), and CL T_0 and CL T_2 ($P < 0.001$).

Due to the heterogeneity of the VITA scale recorded at T_0, it was impossible to carry out a statistical analysis. From a descriptive point of view, ES and VE showed the best color match between the restoration and the tooth at every measurement time (T_0, T_1, T_2).

CL and OM showed better color matching especially after bleaching procedures, when the color of teeth became brighter.

However, aiming to categorize into levels the different colors of the VITA scale, three groups were created as follows: light (A1, B1, B2, C1, D2), medium (A2, A3, C2, D3, D4) and dark (A3.5, A4, B3, B4, C3, C4). Following this categorization, Table 2 shows the relationship between VITA levels, and composite and tooth.

Where significant *P* values are present, it can be stated that the level of the VITA scale is statistically different between the different composite groups.

Mean Whiteness Index differences (ΔEWI_D) and standard deviations (SDs) were calculated at T_1 and T_2 and are shown in Table 3.

Statistically significant differences ($P < 0.05$) were found at T_1 between OM and ES ($P < 0.001$), OM and VE ($P < 0.001$), OM and CL ($P < 0.001$), CL and VE ($P < 0.001$); at T_2 between OM and ES ($P < 0.001$), OM and VE ($P < 0.001$), OM and CL ($P < 0.031$), CL and VE ($P < 0.001$), CL and ES ($P = 0.018$). Statistically significant differences were shown between OM T_1 and OM T_2 ($P < 0.001$).

DISCUSSION

Nowadays, dental bleaching is probably the most popular esthetic procedure in dentistry,[20] and it can be performed through two different protocols: In-office (performed by a professional) or at-home (prescribed by a professional but performed by the patient at home).[21] As a result, different agent concentrations (carbamide peroxide or hydrogen peroxide) and different application times can be used for bleaching protocols.[22]

Also BE properties of single-shade composites are a current topic in restorative dentistry since these new resins could completely shift the opinion of which material of choice should be used for dental restorations.

To evaluate the shade matching ability of an esthetic resin composite, an inter-national research group evaluated *in vitro* color ΔE_{ab} parameters of three composites, taking into consideration filler morphology and light transmittance characteristics. ΔE_{ab} values of a supra-nano filled composite (Omnichroma) were significantly lower in A2, A3, and A4 VITA scale shades, meaning that a supra-nano filled composite shows better shade matching compared to micro-hybrid filled (Essentia Universal) and clustered-nano filled composites (Filtek Supreme Ultra).[17]

Lately published research tested four single-shade composites (Omnichroma, Charisma Diamond One, Vittra Unique, and Essentia Universal) used to restore 40 human incisors. An instrumental evaluation was conducted using VITA Easyshade Compact V spectro-photometer to calculate ΔE_{ab}. Authors concluded that all tested materials had acceptable color-matching potential, with no significant differences between tooth shades and the tested resin composites.[7] These results are partially in contrast with those of the present manuscript, probably due to the different selection of composites and to the different methodology of specimen production. The behavior of the composites used by both studies is very similar, the main difference lies in the fact that Altınışık and Özyurt did not find statistical differences between composites, while our statistical analysis did find some significant differences.

One of the major limits of the present manuscript is the choice of posterior teeth. Although this choice has been made for convenience, it must be highlighted that enamel and dentin, as well as the color of posterior teeth, are different from anterior elements.[23]

Table 1: Mean color differences (ΔE_{ab}) and standard deviations between T_0, T_1, and T_2

Group	T_0	T_1	T_2
OM	12.5 ± 4.7 (4.1–23.1)^{abAB}	7.7 ± 3.9 (1.5–19.1)^{eA}	6.3 ± 2.6 (2.1–12.2)^{B}
VE	6.9 ± 2.9 (1.8–12.6)^{bdCD}	4.3 ± 2.0 (1.6–8.6)^{efgC}	5.0 ± 2.9 (1.7–13.7)^{D}
ES	7.5 ± 3.9 (1.1–15.6)^{acE}	6.6 ± 3.0 (2.1–14.8)^{gF}	4.4 ± 2.4 (1.7–10.9)^{EF}
CL	12.6 ± 4.1 (4.0–19.1)^{cdGH}	6.2 ± 2.4 (1.6–9.7)^{fG}	6.1 ± 1.8 (2.0–9.3)^{H}

ΔE_{ab} T_0: Statistically significant difference between OM^a and ES^a ($P<0.001$), OM^b and VE^b ($P=0.001$), CL^c and ES^c ($P<0.001$), CL^d and VE^d ($P<0.001$), ΔE_{ab} T_1: Statistically significant difference between OM^e and VE^e ($P<0.005$), VE^f and CL^f ($P<0.001$), VE^g and ES^g ($P=0.023$), Statistically significant difference between OM^A T_0 and OM^A T_1 ($P<0.001$), OM^B T_0 and OM^B T_2 ($P<0.001$), Statistically significant difference between VE^C T_0 and VE^C T_1 ($P=0.003$), VE^D T_0 and VE^D T_2 ($P=0.033$), Statistically significant difference between ES^E T_0 and ES^E T_2 ($P<0.002$), ES^F T_1 and ES^F T_2 ($P=0.016$), Statistically significant difference between CL^G T_0 and CL^G T_1 ($P<0,001$), CL^H T_0 and CL^H T_2 ($P<0.001$). OM: Omnichroma, VE: Venus diamond one, ES: Essentia universal, CL: Clearfil Majesty ES-2 Universal

Table 2: Relationship between VITA levels, composite and tooth

Samples	VITA T0 tooth			VITA T0 restoration			VITA T1 tooth			VITA T1 restoration			VITA T2 tooth			VITA T2 restoration		
	Light	Medium	Dark	Light	Medium	Dark	Light	Medium	Dark	Light	Medium	Dark	Light	Medium	Dark	Light	Medium	Dark
OM	1	10	9	19	1	0	5	12	3	17	3	0	11	5	4	14	6	0
VE	3	10	7	20	0	0	12	8	0	19	1	0	16	4	0	18	2	0
ES	3	6	11	3	17	0	9	9	2	7	13	0	11	7	2	9	11	0
CL	2	5	13	3	15	2	13	7	0	4	16	0	8	12	0	6	14	0
Total	9	31	40	45	33	2	39	36	5	47	33	0	46	28	6	47	33	0

Statistically significant differences: T0 R: $P<0.001$, T1 R: $P<0.001$, T2 T: $P=0.019$, T2 R: $P<0.001$. OM: Omnichroma, VE: Venus Diamond One, ES: Essentia Universal, CL: Clearfil Majesty ES-2 Universal, VITA: VITA Classical color scale

Table 3: Mean color differences (ΔWI_D) and standard deviations between T_1 and T_2

Group	ΔWI_D	
	T_1	T_2
OM	11.3 ± 6.7 (0.2–28.9)^{abcdA}	$7.0\pm4.2(-0.8–13.8)^{efgA}$
VE	$-2.3\pm5.4(-11.3–9.1)^{cd}$	$-0.8\pm5.9(-12.8–9.3.7)^{gi}$
ES	$1.1\pm7.9(-11.5–14.5)^{b}$	$-0.6\pm5.9(-11.5–12.5)^{fh}$
CL	$5.4\pm5.4(-8.4–12.0)^{a}$	$3.6\pm5.1(-9.0–9.6)^{ehi}$

ΔEWI_D T_1: statistically significant difference between OM^a and CL^a ($P<0.001$), OM^b and ES^b ($P<0.001$), OM^c and VE^c ($P<0.001$), CL^d and VE^d ($P<0.001$), ΔEWI_D T2: statistically significant difference between OM^e and CL^e ($P<0.031$), OM^f and ES^f ($P<0.001$), OM^g and VE^g ($P<0.001$), CL^h and ES^h ($P=0.018$), CL^i and VE^i ($P<0.001$). Statistically significant difference between OM^A T_1 and OM^A T_2 ($P<0.001$). OM: Omnichroma, VE: Venus diamond One, ES: Essentia universal, CL: Clearfil majesty ES-2 Universal

Several previous studies have analyzed the behavior of single-shade resin composites in comparison with traditional materials, but only a few of them have also evaluated the effect of bleaching treatments.[8,12-14]

A case series conducted by Mohamed *et al*. in 2020 investigated instrumental and visual color match on extracted teeth using Omnichroma composite before and after bleaching.[14] The authors concluded that the shade of the filling matched that of the adjacent enamel pre- and post-bleaching.

Pecho *et al*. evaluated the influence of a professional whitening gel on color and whiteness modifications of three multi-shade resins using ΔE_{ab} formula and concluded that bleaching gel had influenced the color and the whiteness of resin-based composites, although color changes were not clinically perceived and whiteness variations were clinically acceptable.[13] Based on these results, the present protocol considered to cover with the bleaching gel only the teeth, avoiding restorations, in order to not influence composites color. Regarding a possible isolation of the restoration during bleaching procedures, a gel bleaching agent was used, so that it would not flow or cover the composite. Authors preferred to avoid using vaseline precisely to avoid the risk that the vaseline could partially cover the tooth, preventing the correct whitening procedure. Moreover, the composite was not covered also to best simulate clinical procedures.

More recently, a pilot study on six human extracted teeth evaluated visual and instrumental color match of two single-shade resins (Omnichroma and Venus Diamond One), before and after professional bleaching. Both materials seemed to be able to achieve an acceptable color shift of their VITA color values before and after bleaching procedures, and to reach an excellent match grade with the visual analysis.[12]

Based on the positive results of the pilot study, the same study group performed an *in vitro* study analyzing the BE of four single-shade composites (Venus Diamond One, Essentia Universal, Clearfil Majesty ES-2 Universal and Omnichroma), before and after bleaching, using the CIEDE2000 system. Venus and Essentia composites gave the best color match results after tooth bleaching procedures, but all the tested materials showed a good BE before and after professional bleaching.[8] Even if the color variation analysis system used is different from the one adopted in this manuscript (CIEDE2000 vs. CIELAB), it is curious to note how the tendency of the 4 composites to change color following tooth bleaching is very comparable to that found in the present study.

Another potential limitation of the present research could be identified in the selection of the color analysis system. Color science is recently not based only on the CIELAB calculation, because color science associations and researchers suggest studies' report with CIEDE2000 calculation, although very often the two systems have provided overlapping trends and results.[24] The choice to use ΔE_{ab} formula is based on the possibility to compare the present results with further findings from several similar studies that chose the CIELAB calculation to verify the BE of single-shade composites.[5,7,13,17] In a previous study, the color match between tooth and composite restorations was recorded using ΔE_{00} formula.[8] These results are in line with those of the present article, highlighting the fact that regardless of the color analysis system used, the BE results of single shade composites are extremely performant from an esthetic point of view.

Moreover, in the already mentioned previous study, ΔE_{00} formula have been used to verify if single-shade composites were able to match the tooth color also after bleaching procedures. These results were obtained comparing ΔE_{00} values before and after bleaching. In the present study instead, a specific and dedicated index (WI_D) was used to evaluate the level of whiteness of the resin composites.[15] This CIELAB-based whiteness index has been developed specifically for dentistry and has not been used yet to evaluate the BE variation of composites after tooth professional bleaching.

A recent paper published by Perez *et al*. in 2019 studied the whiteness index in dentistry and how to assess the thresholds of whiteness perceptibility and acceptability (WPT and WAT).[15] This study explained that higher values correspond to increasing whiteness mismatches, and therefore poor esthetics and lower patient satisfaction. Lower values instead correspond to higher whiteness matches. Following these thresholds, the whiteness index differences (ΔWI_D) calculated in the present manuscript at T_1 and T_2 show the lowest values, and therefore the highest whiteness matches, for VE, followed by ES, CL, and OM.

Another limitation of this study can certainly be represented by the choice of the spectrophotometer used in this study.

The VITA Easyshade V is a clinical device that illuminates the tooth with a 6500 K light, and it has been used in several studies.[7,8,12] Even though a bench spectrophotometer could represent the most suitable instrument for an *in vitro* study,[25,26] following recent data published in the literature,[10-16] a clinical spectrophotometer was chosen for the present manuscript to reproduce in the most precise way a clinical situation. This device provides accuracy and reliability as reported by a study by Dozić *et al*., which found VITA Easyshade to be, *in vitro* and *in vivo*, the most precise among five other similar devices.[27]

Based on the findings of the present manuscript, the two initial null hypotheses were rejected.

CONCLUSION

Within the limitations of this *in vitro* research, the following conclusions can be deduced:

- The four tested single-shades composites showed a good color correspondence with the surrounding tooth
- This correspondence remains effective also after bleaching procedures.

Based on the relevant results of this *in vitro* research, it would be useful to arrange an *in vivo* instrumental analysis, better if on anterior teeth, to define if single-shade composites are clinically able to match the color of the surrounding tooth, and therefore to confirm the results obtained in the present study.

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Conflicts of interest
There are no conflicts of interest.

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