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Original Article

Effect of bleaching on the color match of single-shade resin composites

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Abstract

Purpose: To evaluate the color match of single-shade resin composites before and after bleaching procedures, through instrumental and visual analyses.
Methods: Class V cavities were created on the buccal surfaces of 80 extracted human molars, restored with 4 single-shade composites (Omnichroma; Clearfil Majesty ES-2 Universal; Essentia Universal; Venus Diamond One). A spectrophotometer (VITA Easyshade V) was used to evaluate the tooth/resin color match before (T_0), and 24 h (T_1) and one week (T_2) after dental bleaching (Opalescence Boost PF 40%). Color variations (ΔE_{00}) were calculated and statistically analyzed ($P < 0.05$). Visual analysis was performed before and after tooth bleaching.
Results: Spectrophotometric evaluations revealed statistically significant differences between materials at T_0, T_1, and T_2 ($P < 0.05$). Visual analysis reported excellent and very good grades (0 and 1, respectively), irrespective of the materials and timepoints.
Conclusion: Data seem to indicate that single shade composites are able to shift their color when the surrounding tooth undergoes bleaching effects. Single-shade composites seem to achieve a good color match with the surrounding tooth structure, before and after professional bleaching.

Keywords: color perception, composite resins, dental restorations, tooth bleaching

Introduction

Among restorative materials, resin composites are widely used for their enhanced esthetics and improved handling properties, as well as presenting reliable mechanical characteristics [1].

Currently, restorative dentistry is linked indissolubly with esthetics, and composite materials should perform perfectly in terms of color match with the shades of the restored tooth [2].

Many parameters are involved in obtaining an accurate color match, and these can be related to teeth or to the resin composite. Characteristics such as value, chroma, hue, opalescence, translucency, transmission and diffusion of light, and surface texture are mainly called into question when dealing with color correspondence analysis [3].

The match between composite and tooth is of fundamental importance when carrying out the reconstruction of an anterior tooth or in the smile region. In this case, it is not possible to accept esthetic compromises and the reconstruction must blend perfectly with the surrounding dental tissues [2].

It is not always easy to uniquely determine the color of a tooth, due to the structural variability of the tooth substrate. Accordingly, composite materials have undergone several improvements over time to minimize these inherent tooth variations, and currently dentists dispose of materials with different shades, mostly by referencing the VITA Classical shade guide. These shades are mainly characterized by pigments and dyes incorporated into the resin matrix [4]. In addition, resin composite presents different opacities (Enamel = translucent, Dentin = opaque/body) that are useful to reach optical properties similar to that of natural dental substrates [1]. Both opacities and chromas of resin composites are clinically used in multiple layers according to the layering technique, in order to create a restoration with the same optical properties as the natural tooth [5]. This technique has made it possible to obtain excellent esthetic restorative results, but it is highly time-consuming and requires an experienced and skilled operator [1].

The ability of a resin to match the color of the surrounding tooth structure via reflections is called Blending-Effect (BE) or the Chameleon-Effect. This phenomenon represents the innovation of the latest generation of resin composites that are supposed to perfectly blend with the surrounding tooth while minimizing the number of shades [4,6]. According to a recent study, the blending ability of recent resin composites significantly contributes to achieving a proper shade match with the tooth and improving the esthetics [4]. Very recently, innovative single-shade composites have been introduced in the market, that are supposedly able to match all VITA Classical shades, from A1 to D4 [1,7-9].

Dental bleaching is an increasingly frequent aesthetic request from patients, either for purely aesthetic needs or for discolorations due to intrinsic or extrinsic factors (drinks, foods, or smoking habits) [10-13]. Although composite resins are subjected to staining during functions, it is noteworthy that the same dental bleaching procedures adopted for natural teeth are ineffective to modify the shade of resin composites [12]. As a consequence, bleaching is usually performed before restorative procedures to obtain the maximum match between the restoration and the newly achieved, lighter tooth shade [13].

To the author's best knowledge, no studies have focused on the evaluation of the color match between different single-shade resin composites with the surrounding tooth before and after professional dental bleaching procedures.

Therefore, the aim of this *in vitro* study was to evaluate the instrumental and visual color match of four different single-shade resin-based composites with the surrounding tooth, before and after professional bleaching procedures performed on extracted human teeth. In particular, the null hypotheses tested were that 1) there is no color match between single-shade composites and the surrounding tooth; and 2) that single-shade resin composites cannot match the tooth shades after dental bleaching.

Materials and Methods

Eighty sound, human molars extracted for periodontal or orthodontic needs were stored at 4°C until use [14], no longer than 1 month. Extracted teeth were used according to Ethics Committee of the University of Bologna approval (protocol N°:71/2019/OSS/AUSLBO). In order to be eligible for this research, the teeth had to be free of caries, restorations, and endodontic treatment.

A standardized class V cavity (2 mm depth x 2 mm high x 4 mm width) was performed on each buccal side of the teeth, 2 mm above the cemento-enamel-junction (CEJ). The cavities were prepared using a water-cooled dedicated round-shape diamond bur (#6801314029, Komet Dental,

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Table 1 Details of resin composites used in the study

Code	Composites	Manufacturer	Matrix	Filler system
OM	Omnichroma	Tokuyama Dental (Tokyo, Japan)	UDMA TEGDMA	SiO_2, ZrO_2, CF (68 vol.-%; 79 wt%; 0.2 µm – 0.4 µm in ø)
CL	Clearfil Majesty ES2 Universal	Kuraray Medical Inc (Tokyo, Japan)	Bis-GMA hydrophobic aromatic dimethacrylate	SBG, PPF (40 vol.%; 78 wt.%; 0.37 µm – 1.5 µm in ø)
ES	Essentia Universal	GC Corp. (Tokyo, Japan)	UDMA	Sr, LaF_3, SiO_2, FAISi glass, Fumed silica (81 wt.%; 16 µm – 16 nm)
VE	Venus Diamond One	Kulzer GmbH (Hanau, Germany)	UDMA TCD-DI-HEA TEGDMA	BaAlF, SiO_2 (64 vol.-%; 81 wt%; 5 nm – 20 µm in ø)

UDMA, urethane dimethacrylate; TEGDMA, triethylene glycol dimethacrylate; TCD-DI-HEA, 2-propenoic acid; (octahydro-4,7-methano-1H- indene-5-diyl) bis(methyleneiminocarbonyloxy-2,1-ethanediyl) ester; SiO_2, silica; ZrO_2, zirconia; CF, composite filler; BaAlF, barium-aluminum-fluoride glass; PPF, pre-polymerized filler; Sr, strontium Glass; LaF_3, Inthanoid fluoride; SBG, silanated barium glass; ø = diameter

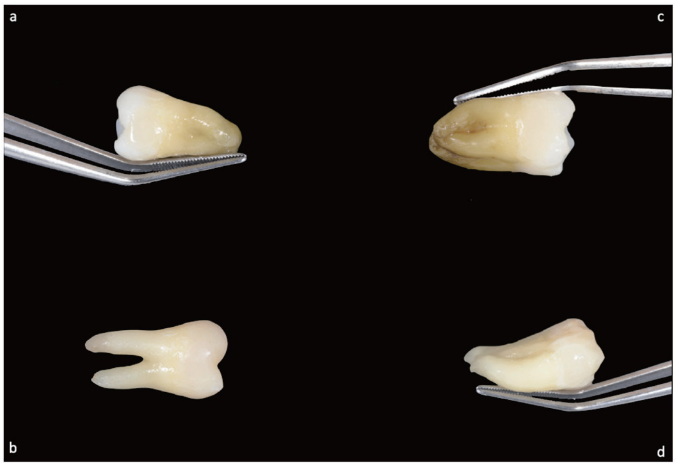

Fig. 1 Class V restorations after polishing procedures (a = OM, b = CL, c = ES, d = VE)

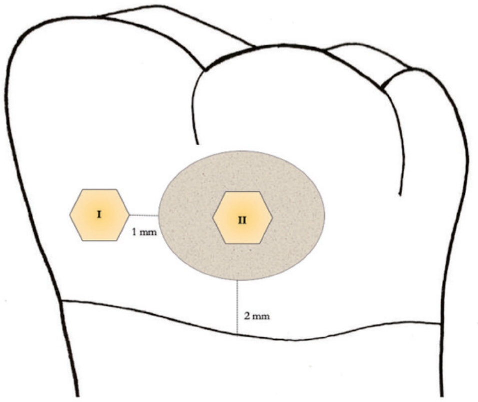

Fig. 2 Color measurement areas (0.5 mm × 0.5 mm) on the restored tooth. Area I: tooth area of 1 mm away from the border of resin composite restoration; Area II: resin composite area of the center of resin composite restoration

Lemgo, Germany) that was discarded and replaced every 2 teeth [15], and beveled with a finishing bur (#8390314016, Komet Dental).

The teeth were randomly distributed in 4 groups, according to the single-shade resin composite/adhesive system used for the restorations (n = 20): Omnichroma/Universal Bond, OM (Tokuyama Dental, Tokyo, Japan); Clearfil Majesty ES-2 Universal/Clearfil Universal, CL (Kuraray Medical Inc., Tokyo, Japan); Essentia Universal/G2 Bond Universal; ES (GC Corp, Tokyo, Japan); Venus Diamond One/iBond Universal, VE (Kulzer, Hanau, Germany). The details of the materials employed in the study are given in Table 1.

The sequence in which the restorations were performed was previously randomized and the operator was blinded to the resin composites. Bonding procedures were performed according to their manufacturers and then a single increment of the resin composites was applied. Composite restorations were then polymerized at 1,400 mW/cm^2 with a middle-intensity blue LED light-curing unit (Mectron Starlight Pro, Genova, Italy) for 40 s, as indicated by the manufacturer.

After curing procedures, the restorations were dry polished with a dedicated composite finishing and polishing system (Clearfil Twist DIA, Kuraray Medical Inc.), using a slow-speed handpiece at 4,000 rpm for 30 s (Fig. 1). Teeth were then stored in distilled water at 37°C for 24 h [14,16].

Bleaching procedures

After restorative procedures, the teeth were fixed on a wax support [12]. A 40% hydrogen peroxide gel (Opalescence Boost PF 40%, Ultradent, South Jordan, UT, USA) was applied to cover the whole tooth surface except for the composite restoration. Two consecutive simulated bleaching sessions, 20 min each [16], were performed for each tooth according to the manufacturer's instructions.

After bleaching, the gel was gently removed using gauze soaked in distilled water and then the specimen's surfaces were washed out and dried with absorbent paper [12].

Instrumental color measurements

An intraoral spectrophotometer (VITA Easyshade V, VITA Zahnfabrik, Bad Sackingen, Germany) was used for color evaluations. The following variables were evaluated: CIELAB color coordinates (L*: lightness, a*: green-red coordinate and b*: blue-yellow coordinate), chroma (C*), and hue (h°) of the teeth (measurement 24 h after the restoration, T_0). A neutral gray paper was used as a background during measurements [6,17], and the device was calibrated after every 3 measurements [6]. Measurements were taken at the center of the restoration and on the tooth, 1 mm away from the margin of the restoration (Fig. 2) [14]. The tip of the device, 0.5 mm in diameter, was placed perpendicularly in contact with the surfaces, as indicated by the manufacturer, and the time of exposure was given by a spectrophotometer.

The CIEDE2000 color differences (ΔE_{00}) between tooth and restoration were calculated using an excel spreadsheet for implementing the CIEDE2000 color difference formula as suggested by Sharma [6,18]:

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T \left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right) \right]^{1/2}$$

The parametric factors of the formula were set to 1 [1,6,18]. Color match evaluations were performed before (T_0), after 24 h (T_1), and after one week (T_2) of the bleaching procedures.

Visual color measurements

After instrumental evaluation, visual color assessments were carried out by 16 dental professionals, 50% males and 50% females, with at least 5 years of experience [6]. A viewing booth was used for this evaluation, and the observation time was controlled during visual analysis, not exceeding 25 s [6]. All evaluators passed the test for color matching competence in dentistry according to ISO/ TR28642 [19].

Under the illumination of a D65 light source and using a 0°/45° viewing geometry, the observers performed blind visual evaluations of all specimens in random order [1]. The color differences between each tooth and restoration were graded from 0 to 4, using the scale based on a previous study where level "0" means excellent match; 1, very good match; 2, not so good match (border zone mismatch); 3, obvious mismatch; and 4, huge (pronounced) mismatch [1,20].

Statistical analysis

Statistical analysis was performed using STATA program version 14 (StataCorp LLC, College Station, TX, USA). The statistician was blinded to the groups when performing the analysis. Means, standard deviations, counts, and percentages were used to summarize the data. The mean effect of the groups was determined using analysis of variance (ANOVA). Prior to the ANOVA test, Levene's Test for Equality of Variances was performed. If the Levene test is positive ($P < 0.05$) then the variances in the different groups are different (the groups are not homogeneous) and it may be necessary to apply a logarithmic transformation to the data or use a non-parametric statistic. In the present data, the Levene test was $P > 0.05$ and no logarithmic transformation was needed. 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. The Cronbach's alpha test was used to analyze the reliability between the evaluators. The Pearson correlations test was used to analyze the coefficient of correlation (r) between data from tests. One-way ANOVA was performed to compare the effects of color differences ΔE_{00} value among the materials. Paired *t*-tests were used to compare continuous measurements between groups. A *P*-value of ≤0.05 was considered statistically significant.

Table 2 Mean and standard deviation values of color differences (ΔE_{00}) between tooth and restoration for different periods (T_0, T_1, and T_2)

Group ΔE_{00}	T_0	T_1	T_2
OM	7.6 ± 2.4 (3.3-13.8)^{abAB}	4.7 ± 1.9 (1.4-8.8)^{eA}	4.3 ± 1.9 (1.5-9.1)^{hiB}
CL	7.3 ± 2 (2.6-9.8)^{cdCD}	3.9 ± 1.4 (1.2-6.2)^{fC}	4.0 ± 1.1 (1.5-5.9)^{lD}
ES	4.2 ± 1.9 (0.9-8.5)^{acE}	4.3 ± 2.1 (1.6-11.3)^{gF}	2.9 ± 1.6 (1.1-8.2)^{hlEF}
VE	3.8 ± 1.5 (1.5-6.2)^{bdG}	2.7 ± 1.2 (1.5-5.4)^{efgG}	3.2 ± 1.9 (1.2-9.1)^{i}

ΔE00-T_0: statistically significant difference between OM^{a} vs. ES^{a} ($P < 0.001$), and OM^{b} vs. VE^{b} ($P < 0.001$); difference between CL^{c} vs. ES^{c} ($P < 0.001$), and CL^{d} vs. VE^{d} ($P < 0.001$); T_1: statistically significant difference between OM^{e} vs. VE^{e} ($P = 0.001$), and CL^{f} vs. VE^{f} ($P = 0.001$), and ES^{g} vs VE^{g} ($P = 0.015$); T_2: statistically significant difference between OM^{h} vs ES^{h} ($P = 0.026$), OM^{i} vs VE^{i} ($P = 0.044$), and CL^{l} vs ES^{l} ($P = 0.009$); statistically significant difference between for OM^{A} between T_0 vs T_1 ($P < 0.001$) and OM^{B} between T_0 vs T_2 ($P < 0.001$); CL^{C} between T_0 vs T_1 ($P < 0.001$) and CL^{D} between T_0 vs T_2 ($P < 0.001$); ES^{E} between T_0 vs T_2 ($P = 0.012$) and ES^{F} between T_1 vs T_2 ($P = 0.031$); VE^{G} between T_0 vs T_1 ($P = 0.008$).

Table 3 Visual color-analysis differences between T_0 and T_2

T_0	Excellent match	Very good match	Not so good match	Obvious mismatch	Total
OM	150 (46,9)	136 (42,5)	34 (10,6)		320 (100)
CL^{a}	160 (50)	136 (42,5)	24 (7,5)		320 (100)
ES	173 (54,1)	124 (38,8)	23 (7,2)		320 (100)
VE^{b}	177 (55,3)	114 (35,6)	29 (9,1)		320 (100)
Total	660 (51,6)	510 (39,8)	110 (8,6)		1280 (100)
T_2					
OM^{cd}	165 (51,6)	119 (37,2)	32 (10)	4 (1,3)	320 (100)
CL^{aef}	144 (45)	133 (41,6)	38 (11,9)	5 (1,6)	320 (100)
ES^{ce}	159 (49,7)	145 (45,3)	14 (4,4)	2 (0,6)	320 (100)
VE^{bdf}	176 (55)	130 (40,6)	14 (4,4)		320 (100)
Total	644 (50,3)	527 (41,2)	98 (7,7)	11 (0,9)	1280 (100)

Statistically significant differences were observed between CL^{a} T_0 and CL^{a} T_2 ($P = 0.029$), and between VE^{b} T_0 and VE^{b} T_2 ($P = 0.043$). Significant differences were observed at T_2 between OM^{c} and ES^{c} ($P = 0.016$), OM^{d} and VE^{d} ($P = 0.008$), CL^{e} and ES^{e} ($P = 0.003$), difference between CL^{f} and VE^{f} ($P = 0.000$).

Results

Mean color differences (ΔE_{00}) and standard deviations (SDs) between the tooth and restored composite at baseline (T_0), 24h (T_1), and 1 week (T_2) after bleaching for each of the composite materials are presented in Table 2. The statistical analysis revealed a significant difference between materials ($P < 0.05$) at T_0, T_1, and T_2.

In detail, at T_0, OM and CL showed higher ΔE_{00} values than ES and VE, with statistically significant differences between OM and ES ($P < 0.001$), OM and VE ($P < 0.001$), Cl and ES ($P < 0.001$), and CL and VE ($P < 0.001$).

At T_1, OM CL and VE showed a ΔE_{00} decrease compared to T_0 values, whereas ES remained stable. Statistically significant differences were recorded between OM and VE ($P = 0.001$), CL and VE ($P = 0.001$), and ES and VE ($P = 0.015$).

Finally, at T_2, all materials showed a further ΔE_{00} decrease and these values appeared more aligned between each other. OM appeared to be the composite with the highest ΔE_{00} values. Statistically significant differences were recorded between OM and ES ($P = 0.026$), OM and VE ($P = 0.044$), and CL and ES ($P = 0.009$).

Table 3 shows how the 16 observers evaluated the match between reconstruction and natural tooth after 24 h from restorative procedures (T_0) and one week after whitening (T_2). The color mismatch, as graded by the evaluators, is graphically represented in Fig. 3a and b. The majority of results fit into the range 0 and 1 (excellent match and very good match).

The statistical analysis of visual data revealed significant differences for CL at T_0 and T_2 ($P = 0.029$), and for VE at T_0 and T_2 ($P = 0.043$). No significant statistical differences were observed between materials at T_0 ($P > 0.05$), but significant differences were present at T_2 between OM and ES ($P = 0.016$), OM and VE ($P = 0.008$), CL and ES ($P = 0.003$), and CL and VE ($P = 0.000$).

Discussion

Recent innovations have focused on the use of filler morphology in order to condition color match between composite and tooth. This "structural color" technology is based on the interaction of light refraction and reflection with supra-nano particles. This phenomenon leads to single-shade resin composites which aspire to match all shades of the VITA color guide [7].

The Commission Internationale de l'Eclairage (CIE) has been traditionally involved in colorimetry for dental materials. It has introduced the main color systems, illumination patterns, and color difference (ΔE) concepts used in color science [16]. When considering CIELAB color space (L*: value axis; a*: red-green axis; b*: yellow-blue axis), ΔE_{ab} has classically been considered the standard parameter for color difference between two objects. In the CIELAB metric, the greater the value, the larger the color difference and, consequently, the more perceptible the difference to the human eye. Aiming to improve the correction between computed and perceived color differences, the CIE recommended the use of CIEDE2000 color-difference formula (ΔE_{00}) [17,21].

In 2021, a research group tested three different composites (Omnichroma, Tetric EvoCeram and TPH Spectra ST) to restore 75 occlusal cavities on resin teeth [6]. ΔE_{00} of all reconstructions was calculated with the VITA Easyshade V spectrophotometer, and 30 evaluators gave their opinion on the color match using a visual scale from 1 (best match) to 3 (poor match). Tetric EvoCeram showed similar ΔE_{00} values in all cases, independently from the VITA color of the resin teeth. Omnichroma and TPH Spectra ST instead showed lower ΔE_{00} values on teeth with brighter VITA colors. The visual analysis showed the best color matches of TE with darker resin teeth (VITA C2 and D3), and of TS with brighter resin teeth. The authors concluded that color match is composite and color dependent [6].

The results of this study, concerning Omnichroma, showed how this material had better results when matching lighter VITA scale tooth shades (A2, B1 and B2). These findings are similar to the results of this manuscript where OM shows a ΔE_{00} reduction after bleaching procedures (T1 and T2), therefore on brighter tooth shades.

Another recent *in vitro* study tested 120 resin teeth, with shades A1 to A4, that were filled with occlusal restorations performed with three different composites: supra-nano filled (Omnichroma), micro-hybrid filled (Essentia Universal), and clustered-nano filled (Filtek Supreme Ultra). Color parameters were registered through ΔE_{ab} and ΔE_{00}. These values appeared significantly lower when supra-nano filled composites were used to restore teeth with A2, A3 and A4 shades, leading therefore to a better color match [4].

In contrast to the findings of the present manuscript and those of Iyer et al. [6], Omnichroma showed lower ΔE_{ab} e ΔE_{00} for all VITA scale tooth shades (A2, A3 and A4) after 24 h from the restoration, equivalent to T_1 timing of the present manuscript. Lastly, in the case of A1 tooth shade, the

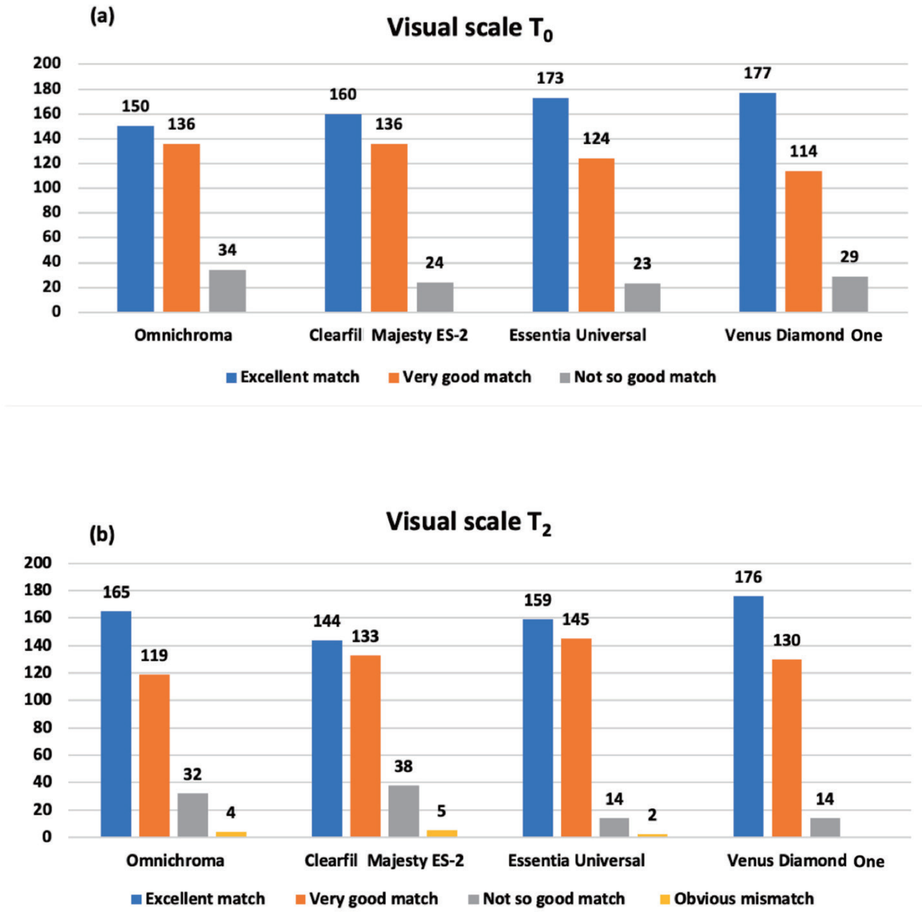

Fig. 3 T_0 (a) and T_2 (b) results of the visual analysis. The majority of the evaluations were in the range of values between 0 (excellent match) and 1 (very good match)

authors found that Essentia Universal had the best match.

Twenty A2-shade extracted premolars were used for another color-match study. Cylindrical cavities 3.0 and 1.5 mm in depth were created in the center of the buccal area and were restored with 4 A2-shade composites (Clearfil AP-X, Clearfil Majesty, Tetric N Ceram e Ceram X). The color was measured with a spectrophotometer (Crystaleye) in 4 areas: on the tooth, 1 mm from the margin of the restoration; on the tooth, 3 mm from the restoration margin; on the restoration, 0.3 mm from the margin; on the restoration, 1 mm from the margin. ΔE_{ab} was calculated between the different areas and ΔE 2/3 and ΔE 1/4 were used to evaluate color shift between tooth and restoration. For all composites, ΔE 2/3 showed lower values than ΔE 1/4, and ΔE 1 and 2 were higher than ΔE 3 and 4. The authors concluded that all composites showed a color shift at the margin of the restorations [14].

In this article, Tsubone et al. tested Clearfil Majesty, the multi-shade version of Clearfil Majesty ES 2 Universal, and concluded that, after 24 h from the restoration, the diffused light transmission property of the composite could produce a chameleon effect due to the reflection of the surrounding tooth.

In order to improve dental esthetics, professional bleaching has become a common treatment in dental clinics [12]. Bleaching can sometimes remove acquired stains on composites and return them to their original shade. However, bleaching is not able to change the shade of composite restorations to a lighter color as it would on a natural tooth structure [13,21,22].

One study evaluated the influence of a professional bleaching gel on the color changes of resin composites. Ten discs were created from three different composite resins (Durafill, IPS Empress Direct, Amelogen Plus), and three sub-groups were obtained for each resin: before bleaching (T_0), after the first (T_1) and the second (T_2) bleaching application. ΔE_{ab} and ΔE_{00} coordinates were obtained through a spectrophotometer (VITA Easyshade) for each period. L* values from all resins did not change after bleaching and there were no statistically significant differences in color variations among all tested materials. The authors stated that bleaching with 35% hydrogen peroxide influences the color of the restoration, but that this influence is not clinically perceived [12].

For this reason, in this *in vitro* study, a selective bleaching procedure was adopted in order not to influence the color of the composite.

Another study group investigated color variations after bleaching using a universal one-shade composite (Omnichroma). Ten extracted sound teeth were prepared with a cervical cavity and then restored with Omnichroma. Visual analysis was performed by two examiners and instrumental analysis was carried out through a Crystaleye spectrophotometer on 5 points of the composite restoration. After professional bleaching, L*, a*, and b* values were registered after 24 h, 1, 2, and 4 weeks after bleaching procedures. These values were then compared to the initial ones. There was no significant difference between L*, a*, and b* values between tooth and restoration at each time interval, and clinicians' scores showed a perfect match between tooth and composite at all intervals [13].

The results of this study agree with the findings of the present manuscript since after bleaching procedures Omnichroma is able to show a very good match with the surrounding structures.

As shown in Table 2, color differences at T_0 between tooth and restoration appear to be less perceivable for ES and VE groups (4.2 ± 1.9 and 3.8 ± 1.5) than for OM e CL groups (7.6 ± 2.4 e 7.3 ± 2). However, this difference decreases at T_1 and to a greater extent at T_2, reaching ΔE_{00} values of 4.3 ± 1.9 for OM, 4.0 ± 1.1 for CL, 2.9 ± 1.6 for ES, and 3.2 ± 1.9 for VE. This result could be explained by the fact that OM and CL are particularly capable to adapt themselves to brighter teeth, as stated also by Iyer et al. [6].

In relation to the visual analysis, at T_0, 91.4% of all evaluations ranged between "excellent" and "very good" for all groups, no negative match was graded, and no statistically significant differences were detected between the four tested materials ($P > 0.05$). At T2, one week after bleaching procedures, 91.5% of observers judged the clinical results as "excellent" and "very good", and only 0.9% evaluated the color match as "obvious mismatch".

The tendency for different results between instrumental and visual analyses could be explained by the fact that color perception does not provide metric-determined results, and an important role is played by the surrounding structure. This can be explained by the theory that the color perception of a composite resin observed alone is different than the color of the same composite used as a restoration with the whole tooth structure surrounding it [23].

Both initial null hypotheses were rejected, and, within the limitations of this study, it can be concluded that all single-shade resin composites tested showed the best color match with the surrounding tooth after 1 week from the bleaching procedures. Moreover, from a visual point of view, the match between restoration and tooth of all single-shade resin composites tested appeared to be excellent or very good, either before or after bleaching.

Based on the significative results of this study, it would be of interest to perform an *in vivo* instrumental and visual analysis, to determine if single-shade resin composites are clinically able to match the color of the surrounding tooth.

Single-shade composites seem to be a valid clinical option in the restoration of class V cavities, and their clinical management is less time consuming and less skill dependent than traditional multi-layer restorative materials.

The results obtained from the visual analysis were more performant than those obtained with the instrumental analysis. This can be explained by the strong influence that the subjective component has on the perceptive one and by the fact that the perception of color influences the visual result. Therefore, contrary to a purely instrumental and scientific point of view, the most important component for the clinician and the patient is the visual one, i.e. the color perception of the tooth-reconstruction complex.

Following the results of this *in vitro* study, data seem to indicate that single shade composites are able to shift their color when the surrounding tooth undergoes bleaching effects.

Conflict of Interest

The authors declare that they have no conflict of interest.

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