Research Article

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The assessment of color adjustment potentials for monoshade universal composites

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Abstract

Objective – To evaluate the color adjustment potentials of monoshade universal composites in different shades of class I cavities.

Methodology – About 132 restorations were performed using monoshade universal composites (Omnichroma, OMNI; Essentia Universal; EU; Charisma Diamond One, CDO), and one simplyshade composite (NeoSpectra-ST, NEO) as control. A transparent silicone mold was used to provide standardized restorations on prefabricated class I cavities of acrylic dentures in B1, A2, and C4 shades. The assessment of color adjustment was performed immediately after, at 24 h, and at 2 weeks, through the cross-polarized dental photographs. The quantitative assessments were performed using a software (Digital Color Meter, Macintosh AC). The collected L^*, a^*, and b^* coordinates from the restorations and the adjacent denture surfaces were used to provide ΔE^*_{00} values. Shapiro–Wilk, three-way Anova and Tukey HSD Test were used for the statistical analyses ($p < 0.05$).

Results – Among all composites and shades, the ΔE^*_{00} values were significantly the highest (1.27 ± 0.49^a) for the immediately after assessments compared to the assessments at 1 day (1.01 ± 0.41^b) and 2 weeks (0.97 ± 0.4^c)($p < 0.05$). At 24 h and 2 weeks of evaluations, the ΔE^*_{00} values for the control (0.42 ± 0.16^H) were significantly the lowest ($p < 0.05$). Only the control presented imperceptible color changes for all the cavity shades (PT ≤ 0.8). After 2 weeks, EU (1.06 ± 0.32^F) and OMNI (1.12 ± 0.18^{EF}) presented significantly lower ΔE^*_{00} values compared to the CDO ($1.29 \pm 0.2C^D$) ($p < 0.05$). Restorations in lighter cavities presented significantly lower ΔE^*_{00} values.

Conclusion – Monoshade universal composites presented acceptable but perceptible color adjustment potentials in class I cavities without the shade selection procedure. Simplyshade composites following the shade selection might still be the best options regarding the level of color adjustment. Monoshade universal composites might provide better color adjustments in cavities with lighter shades.

Keywords: color adjustment potential, color match, composite, monoshade universal, simplyshade

1 Introduction

The objective of restorative dentistry is to create natural alike as well as long-lasting restorations in clinical practice. Resin composites are one of the best solutions for minimally invasive restorations even for the anterior and the posterior dentition [1]. Dental trauma and especially poor oral hygiene might lead to the presence of caries, tooth wear, and also congenitally missing teeth, which are the most common reasons for the placement of direct composite restorations [2]. However, the shade selection of the resin-based composite material could be a real problem clinically. The development of resin-based composite materials aimed to enhance the color adjustment to inhibit the irreversible problems related to the shade selection of the restoration material [3]. Accordingly, new monomers, filler type, size and ratio, content variation, and silanization have been used to improve the physical and mechanical properties of contemporary composites [4,5]. Therefore, with regard to these improvements, the resin-based composites are now better restorative options in both mechanical and optical terms, for direct posterior as well as anterior esthetic restorations [6].

A composite restoration should be in harmony with the surrounding dental tissues as well as the adjacent teeth. Following the selection of the restorative material type, proper shade selection of the selected material is also very important for the esthetic outcome [2]. There are

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various resin-based materials in the market with different levels of color adjustment potential. The ones with the higher level of blending effect have the advantage to reduce the probability of shade mismatch [1,7]. The clinician should experience the material's color parameters such as translucency, chroma, opalescence, and fluorescence previously, to succeed in more complex clinical cases [3]. Moreover, the mechanical and optical properties of the selected material might change during the composite layering procedure according to the thickness of the layers applied [1,2]. Especially dentin layering acts as an important factor in the perception of the primary color of the tooth and the level of permeability. Also, the thickness of the enamel layer influences the final color and value of the restoration [6,7].

The color of resin composites has three basic components, such as value, chroma, and hue, which are involved in various levels for different resin-based materials. The interaction of these three parameters eventually generates the final color of the material. Value refers to the amount of light reflected from the tooth surface and has the most remarkable impact in the final shade of the restoration [8]. When the chroma increases the value decreases, which might be interpreted that the more chromatic shades have generally less opacity. Accordingly, due to the difficulties in shade-selection of the resin-based materials, manufacturers have been trying to produce optically smarter materials that can reflect the color of the surrounding dental tissues to provide a natural alike color adjustment [1]. The composite kits including more than five shades might generally be called polyshade composites [9]. The kits including shades from two to five might be called simplyshade composites [1,9]. Moreover, recently some manufacturers have released the monoshade universal composites which are claimed to mimic all 16 shades of Vita Classical Guide [9]. The color adjustment mechanism of these unique materials depends on the amount of surrounding intact natural dental tissue [1,2]. Therefore, the dentist should understand the indication of these materials well, clinically.

The level of color change/adjustment is assessed either visually or by instrumental. Visual shade assessment by using a shade guide is a subjective method and might be affected by various factors such as observers' skills, gender, age, and lighting conditions. Despite these subjective factors, the visual method is still the most preferred shade-taking procedure, clinically [2]. As a result of the objective outcomes of the instrumental assessment, many instruments have also been preferred for shade-taking. Other than the worldwide accepted spectrophotometers and colorimeters, digital cameras, intraoral scanners, and also smartphones can be used as alternative instruments [9,10]. However, digital cameras have different parameters such as light source, exposure time, white balance, shutter speed, aperture, resolution, and shooting angles and directions which all might adversely affect the selection procedure [2,9]. Recently, an objective and quantitative method, dental photography with cross-polarizing (CP) filters, have been considered one of the most effective and accurate shade selection techniques [1,9,11]. The use of CP filter photography eliminates the unwilling light reflections, which might cause shade mismatching, therefore providing more standardized and homogeneous lighting on the tooth surface [10–12]. Following a selected instrumental shade-taking procedure, the most widely used system for the quantitative analysis of the color change or match/mismatch is the CIE $L^*a^*b^*$ color space developed by CIE (Commission Internationale de Leclaire – CIE) [1,10]. To achieve a better correlation with visual perception, recently ISO (International Standard Organization) and CIE have both recommended the use of CIEDE 2,000 color space for the color difference calculations [13].

This *in-vitro* study aims to assess the color adjustment potential of three different monoshade universal composites layered in class I restorations of artificial dental models and also to evaluate the level of shade matching in three different cavity shades of the models. The hypotheses (h_0) of the study are as follows: (1) the level of color adjustment between the control and the experimental groups is similar, (2) the level of color adjustment for different cavity shades is similar, and (3) the level of color adjustment for the monoshade universal composites does not differ in time.

2 Methods

2.1 Preparation and distribution of samples

A supra-nano monoshade universal composite (Omnichroma, OMNI, Tokuyama, Japan), a microhybrid monoshade universal composite (Essentia Universal, EU, GC Corp., Japan), a nano-hybrid monoshade universal composite (Charisma Diamond One, CDO, Kulzer Gmbh, Germany), and a nano-hybrid simplyshade composite (Neo Spectra ST, NEO, Dentsply Sirona, USA) were used for the class I restorations (Table 1).

A total of 132 restorations were performed (n = 11 for each composite) on acrylic mandibular first molar dentures with standardized class I cavities (diameters of 4

Table 1: Type, content, and manufacturer of the resin-based composite materials

Material	Code	Type	Content	Manufacturer
Omnichroma	OMNI	Supra-nano filled	**Organic matrix:** UDMA, TEGDMA, Mequinol, Dibutyl hydroxyl toluene and UV absorber **Inorganic filler:** Spherical silica-zirconia filler. 79 wt%, 68 vol% **Particle size:** 200–600 nm	Tokuyama, Tokyo, Japan
Essentia Universal	EU	Micro-hybrid	**Organic matrix:** UDMA, bis–MEPP, bis–EMA, bis–GMA, TEGDMA **Inorganic filler:** Pre-polymerized fillers (17 µm): strontium glass (400 nm), lanthanide flüoride (100 nm), fumed silica (16 nm), FAlSi glass (850 nm) 81 wt%, 65 vol%	GC Corp., Tokyo, Japan
Charisma Diamond One	CDO	Nano-hybrid	**Organic matrix:** TCD-DI-HEA, UDMA Inorganic Filler: Ba-A-F borosilicate glass, SiO_2 nanofiller. 81 wt%, 64 vol% **Particle size:** 5 nm to 20 µm	Kulzer Gmbh, Hanau, Germany
Neo Spectra ST	NEO	Nano-hybrid	**Organic matrix:** Poly-urethanemethacrylate, bis-EMA, TEGDMA **Inorganic filler:** Pre-polymerized spherical fillers: (15 µm) and 0.6 µm barium glass fillers and 0.6 µm ytterbium flüoride, silicone dioxide nanofillers (10 nm). 77–79 wt%, 59–61 vol%	Dentsply Sirona, DE, USA

Abbreviations: UDMA: diurethane dimethacrylate; TEGDMA: triethylene glycol dimethacrylate; bis-MPEPP: 2,2-bis[(4-methacryloxy polyethoxy)phenyl]propane; bis-EMA: bisphenol A glycol methacrylate ethoxylated; bis-GMA: bisphenol A diglycidil ether dimethacrylate; TCD-DI-HEA: bis(acryloyloxmethyl)tricyclo [5.2.1.02,6] decane.

mm in width and 2 mm in depth) including bevels. The dentures were in three different shades as follows: VITA Classical B1, A2, and C4. No shade selection was performed for the monoshade universal composites (the experimental groups), while it was performed for the simplyshade composite (the control group). A universal adhesive agent was applied before the restorations according to the manufacturer's instructions (Clearfil Universal Bond, Kuraray Noritake, Tokyo, Japan). The restorations were standardized by previously prepared transparent silicone stamp (Exaclear, GC Corp., Japan) (Figure 1). Then, the composites were placed into the cavities, the stamp was applied with a slight press-on force and polymerized with a led curing unit (Valo Grand, Ultradent Products, USA) with irradiation of 1,000 mW/cm^2 for 20 seconds (Figure 2). Following the restorations, the teeth were kept in distilled water at room temperature for 24 h. Shade-matching levels were assessed immediately after, 24 h after, and 2 weeks after the restorations, through the cross-polarized macro photographs. Following the restorations, all the teeth were kept in distilled water at room temperature during the research.

Figure 1: Occlusal stamp preparation by using a transparent silicone material, Exaclear, GC Corp.

2.2 Assessment of color adjustment

Cross-polarized macro dental photographs were taken from each restoration with standardized shooting parameters. Canon Eos 700D (Tokyo, Japan) camera, Canon EF 100mm Macro objective, Canon MT-24EX Macro twin flash, and Polar Eyes (Photomed, USA) cross-polarization filters were used for the CP photography. The distance from the objective to the restoration surface was set at 30 cm with a perpendicular angle (Figure 3). The shooting parameters were set at shutter speed 1/125, aperture f 25, ISO 200, and no white balance calibration was undergone.

The CP photographs were processed in Color Meter software (Classic Version 1.8.1, Macintosh; USA). The quantitative L^*, a^*, and b^* color coordinates were

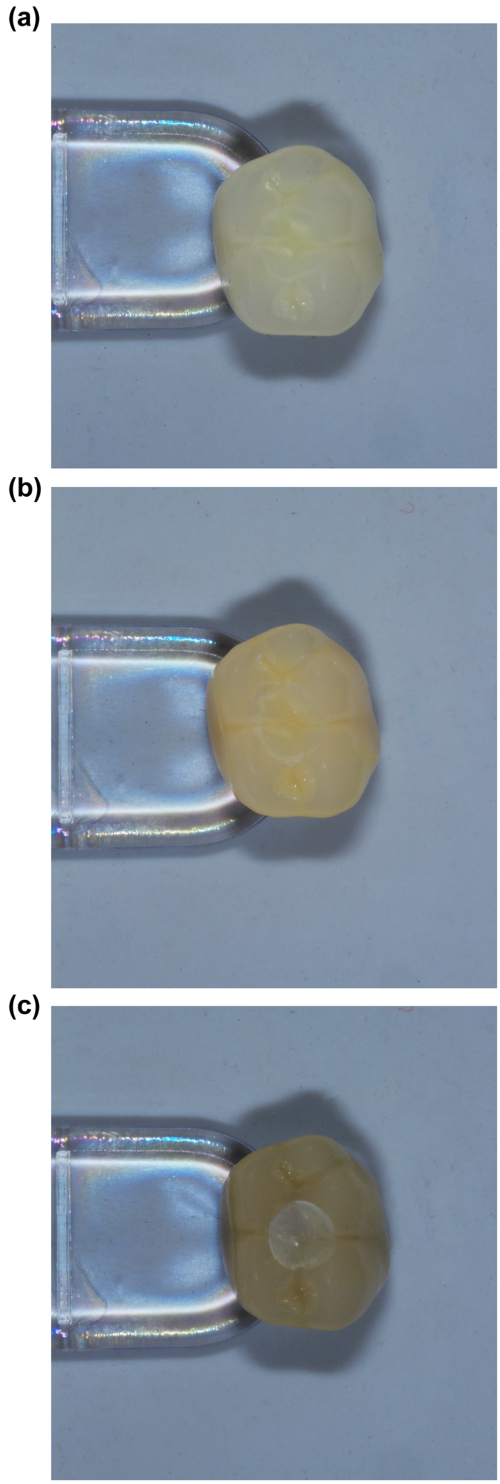

Figure 2: (a–c) Occlusal restorations in different shades of acrylic dentures, immediately after the polymerization (a: B1 shade denture; b: A2 shade denture; c: C4 shade denture).

measured (average of three different measurements) for every restoration and the adjacent denture tissue (Figure 4). Therefore, a shade matching/mismatching value (ΔE^{*}_{00}) was

Figure 3: CP Photography shooting setup.

generated for each restoration using the CIEDE 2,000 formula. The assessments were performed three different times (immediately after, 24 h after, and 2 weeks after the restorations).

The statistical analyses were performed using the Minitab 17 software. Shapiro–Wilk test, three-way Anova test, and Tukey HSD test were used for the analyses. The deem significance was set at $\alpha < 0.05$.

3 Results

Composite type, shade, and time were considered effective factors for the shade adjustment ($p < 0.001$ for each), though the effect of composite type was slightly greater (F: 1176.72; Table 2).

Regarding the monoshade universal composites, OMNI (1.31 ± 0.33^{a}) and CDO (1.35 ± 0.22^{a}) presented similar ΔE_{00} values ($p \geq 0.05$) which were significantly greater than EU (1.2 ± 0.34^{b}) ($p < 0.05$). However, EU presented significantly greater ΔE_{00} values compared to the control group NEO (0.47 ± 0.2^{c}) ($p < 0.05$; Table 3). All restorations with four composite types presented color adjustment levels below the acceptable threshold (AT $\leq$ 1.8). However, the ΔE_{00} values of the composites in the experimental groups were all above the perceptible threshold (PT $>$ 0.8). The shade mismatches were all imperceptible only for the samples in the control group (Table 3).

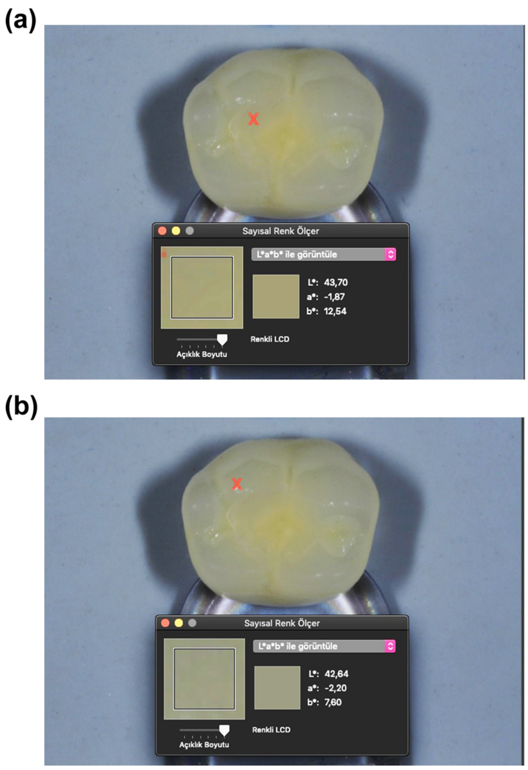

Figure 4: (a and b) Measurement of the quantitative *L**, *a**, and *b** coordinates of the restoration and the denture in Color Mine software.

Table 2: Effect of composite type, shade, and time, and the interactions on color matching

	F	*p*	Eta-square
Composite type	1176.72	<**0.001**	0.907
Shade	477.85	<**0.001**	0.726
Time	240.44	<**0.001**	0.572
Composite type * Shade	17.45	<**0.001**	0.225
Composite type * Time	19.62	<**0.001**	0.246
Shade * Time	4.84	**0.001**	0.051
Composite type * Shade * Time	8.09	<**0.001**	0.212

F: test statistics, *p*: ($p < 0.05$).

Regarding the color adjustment potentials for the cavity shades, ΔE_{00} values were significantly greater for C4 shade cavities (1.33 ± 0.49^{a}), followed by the restorations in A2 (1.04 ± 0.35^{b}) and B1 (0.88 ± 0.4^{c}) shade cavities ($p < 0.05$). The ΔE_{00} values were greater for the darker cavity shades ($p < 0.05$). All the restorations in three different cavity shades presented perceptible but acceptable color adjustments (Table 3).

Regarding the assessment period, the ΔE_{00} values were significantly greater for the immediately after (1.27 ± 0.49^{a}) assessments, followed by 24 h (1.01 ± 0.41^{b}) and 2 weeks (0.97 ± 0.4^{c}) assessments ($p < 0.05$; Table 3). Meanwhile, for all three assessment periods, the color adjustments were considered perceptible but acceptable (PT > 0.8; AT ≤ 1.8).

The highest ΔE_{00} values were observed for the C4 cavities of EU (1.73 ± 0.11^{B}) and the CDO (1.72 ± 0.15^{BC}) composites immediately after the restorations ($p < 0.05$), whereas the lowest ΔE_{00} values were observed for the B1 cavities of EU composite 2 weeks after (0.72 ± 0.14^{OP}) and 24 h after (0.76 ± 0.14^{NO}) the restorations ($p < 0.05$; Table 3). Besides, the color adjustment potential for the control group was considered significantly better among all composites, in terms of the cavity shades ($p < 0.05$).

4 Discussion

This *in vitro* study aimed to compare and monitor the color adjustment levels of the monoshade universal composites in class I restorations. To obtain the isolated effect of the resin composites in shade matching, acrylic dentures in three different shades were used instead of the extracted teeth. The standardization in cavity diameters, depth, and beveling angles was also provided in this way.

When the tooth dehydrates, the interprismatic space is replaced with air and the light refracts differently, giving the tooth a temporary whiter appearance [14,15]. In this study, the teeth were kept in distilled water at room temperature during the study period, as recommended previously [4,6,9]. Many researchers have studied the effect of dehydration and rehydration on natural dental tissues previously [14–16]. Even one minute of dehydration was considered adversely effective on shade selection of restorative materials [15], and at least 24 h was determined as needed for complete rehydration [16]. However, almost no studies have investigated the effect of dehydration and rehydration on the color of restorative materials, yet it might also affect the level of color adjustment of restorations. Accordingly in our study, the dentures with the restorations were kept in distilled water at room temperature during the study to avoid dehydration and the assessments were performed immediately after the removal from the water. In addition, the assessment for the color adjustment of the restorations was performed not only immediately after, but also 24 h and 2 weeks after the restorations were completed.

Color matching is one of the key factors for success in resin composite restorations [7]. Previously indicated gold standard digital shade-taking devices have some

Table 3: Multiple variations anova of the ΔE_{00} values, in terms of composite type, shade, and time

SHADE	TIME	COMPOSITE				Total
		OMNI	CDO	EU	NEO	
B1	Imdt after	1.33 ± 0.08^{DEFGHI}	1.26 ± 0.15^{EFGHIJ}	1.25 ± 0.09^{FGHIJ}	0.36 ± 0.14^{RS}	1.05 ± 0.42^{C}
	24 h	1.07 ± 0.09^{JKLM}	1.16 ± 0.13^{HIJKL}	0.76 ± 0.14^{NO}	0.29 ± 0.11^{S}	0.82 ± 0.36^{E}
	2 weeks	0.93 ± 0.17^{MN}	1.14 ± 0.13^{JKL}	0.72 ± 0.14^{OP}	0.28 ± 0.11^{S}	0.77 ± 0.35^{E}
	Total	1.11 ± 0.21^{D}	1.19 ± 0.14^{CD}	0.91 ± 0.28^{E}	0.31 ± 0.12^{H}	0.88 ± 0.4^{c}
A2	Imdt after	1.41 ± 0.09^{DEF}	1.38 ± 0.11^{DEFG}	1.35 ± 0.08^{DEFGH}	0.62 ± 0.22^{OPQ}	1.19 ± 0.36^{B}
	24 h	1.2 ± 0.05^{GHIJK}	1.25 ± 0.08^{FGHIJ}	1.03 ± 0.06^{KLM}	0.45 ± 0.14^{QRS}	0.98 ± 0.33^{CD}
	2 weeks	1.15 ± 0.06^{IJKL}	1.23 ± 0.08^{FGHIJ}	1 ± 0.06^{LM}	0.43 ± 0.14^{QRS}	0.95 ± 0.33^{D}
	Total	1.25 ± 0.13^{BC}	1.29 ± 0.11^{B}	1.13 ± 0.17^{D}	0.5 ± 0.18^{G}	1.04 ± 0.35^{b}
C4	Imdt after	2.1 ± 0.15^{A}	1.72 ± 0.15^{BC}	1.73 ± 0.11^{B}	0.71 ± 0.18^{OP}	1.57 ± 0.54^{A}
	24 h	1.35 ± 0.1^{DEFGH}	1.53 ± 0.13^{CD}	1.5 ± 0.09^{D}	0.56 ± 0.12^{PQR}	1.23 ± 0.42^{B}
	2 Weeks	1.26 ± 0.08^{EFGHIJ}	1.51 ± 0.14^{D}	145 ± 0.09^{DE}	0.54 ± 0.12^{PQR}	1.19 ± 0.4^{B}
	Total	1.57 ± 0.4^{A}	1.58 ± 0.17^{A}	1.56 ± 0.15^{A}	0.6 ± 0.16^{F}	1.33 ± 0.49^{a}
Total	Imdt after	1.61 ± 0.37^{A}	1.45 ± 0.24^{B}	1.44 ± 0.23^{B}	0.56 ± 0.23^{G}	1.27 ± 0.49^{a}
	24 h	1.21 ± 0.14^{DE}	1.31 ± 0.19^{C}	1.1 ± 0.33^{F}	0.43 ± 0.16^{H}	1.01 ± 0.41^{b}
	2 Weeks	1.12 ± 0.18^{EF}	$1.29 \pm 0.2C^{D}$	1.06 ± 0.32^{F}	0.42 ± 0.16^{H}	0.97 ± 0.4^{c}
	Total	1.31 ± 0.33^{a}	1.35 ± 0.22^{a}	1.2 ± 0.34^{b}	0.47 ± 0.2^{c}	1.08 ± 0.45

Ss: average ± standard deviation; A–S: no significant difference between the interactions with the same letter, a–c: no significant difference between the main groups with the same letter.

limitations related mainly to the probe positioning for the assessments of resin-based materials [1,14–17]. The use of cross-polarization (CP) filters with calibrated and standardized shooting parameters is now a worldwide accepted shade analysis technique and by processing the determined color coordinates, a more accurate, quantitative assessment might be performed even for the resin-based materials [13,18]. However, issues such as the standardization of camera settings, lighting conditions, shooting angles, and the shooting distances should be taken into account [1,2,10]. Burki et al. [14] investigated even the effect of dehydration and rehydration on color change in natural dental tissues through macro-dental photographs. de Abreu et al. [18] experimented color adjustment of composites in class III cavities and used CP photography for the quantitative evaluations. Korkut and Turkmen [1], Korkut and Özcan [2], and Korkut et al. [10] retrospectively evaluated the longevity of anterior restorations through the CP dental photographs. Better color matching and translucency was considered previously for scoring through dental photographs than visual scoring [1,2,10]. In our study, to obtain the data for the color adjustment analysis, dental photography with CP filters was considered a reliable and accurate method. CP photography technique was previously indicated for retrospective continuing shade assessments even without white balance calibration [10,19,20]. Therefore, a quantitative assessment of the level of color adjustment could be performed through high-quality digital images by using previously mentioned computer software [12]. In addition, the subjectivity in shade selection was minimized, and also with the help of magnification, the digital images became more informative [1,2].

The chameleon (blending) effect refers to the interaction of restorative material and surrounding dental tissues [10,21]. The level of blending is greater when there is a smaller color difference between these two while observing them together instead of individually [21]. However, previously the blending effect was considered material, shade, and restoration size dependent [21–23]. Consistent with this, the results obtained in this study demonstrated that composite type, composite shade, and assessment time all affected the level of color adjustment of the restorations ($p < 0.05$) (Table 2).

The monoshade universal composites were claimed to have a greater blending effect which works for the clinician by lowering the color mismatches [1,10]. In contrast, according to our results the control group, simplyshade composite NEO presented significantly a better color adjustment level than the monoshade universal composites ($p < 0.05$). This result might be interpreted that the shade-selected simplyshade composites are still a better solution compared to the no shade-selected monoshade universal composites, in terms of the color match of the restoration. The better adjustment was valid immediately after, 24 h after, and 2 weeks after the assessments. Additionally, the level of matching gets significantly better in time. Only the control presented imperceptible color adjustments among all composites (PT ≤ 0.8) (Table 3). Therefore, the first hypothesis of the study is rejected.

Regarding the comparisons between the monoshade universal composites, OMNI presented significantly the worst, while EU was the best color adjustment among all, immediately after the restorations ($p < 0.05$); 24 h after the restorations, CDO was significantly the worst and EU remained the best ($p < 0.05$). However, 2 weeks after the restorations, CDO was again significantly the worst, but OMNI and EU presented similar ($p \geq 0.05$) color adjustments, better than CDO ($p < 0.05$). According to our results, the color adjustment of OMNI got better in time. Therefore, the third hypothesis of the study is rejected. Our results were inconsistent with the recent two-year clinical outcomes of Korkut et al. [10] in which they presented similar color-matching scores for the anterior restorations with OMNI and EU. This difference might be due to the clinical aging parameters influencing the surface roughness, gloss, as well as the final shade of the restoration. Omnichroma has a declared refractive index of 1.47 and 1.52 before and after polymerization, respectively, according to the manufacturer [4]. As a result, the transparency of the material increases after polymerization [4,10,21]. Thus, our results could be considered supporting the previous findings of Kobayashi et al. [4], Paravina et al. [22], and Korkut et al. [10] considering a strong correlation between the chameleon effect and the translucency parameter. Accordingly, Atalı et al. [24] mentioned the higher translucency and sensitive photoinitiator system in OMNI are directly related to the bottom/top hardness of the material after curing, due to the allowing of more curing light to enter, homogenously. Additionally, the smart chromatic technology of OMNI with no additional pigments and also the uniformly sized supra-nano spherical fillers might be the reasons for the observed better color adjustment potential in time [4]. A few previous studies reported significant level of color changes in some older brand composite shades due to the degree of conversion during the polymerization and the changes varied among the resin composites tested [24–27]. Our immediately after assessment results are also inconsistent with the results of de Abreu et al. [18] and Iyer et al. [23] both reporting that multishade composites presented better color adjustment potentials than the monoshade universal omnichroma. As a result, it might be determined that there is a strong effect of the polymerization duration on the color adjustment potential of omnichroma. Greater color-matching ability was reported by Pereira Sanchez et al. [21] for omnichroma on acrylic dentures for both visual and instrumental assessments, but did not mention the time of assessment. But their results are also incompatible with our findings in 2 weeks after the restorations. de Abreu et al. [18] reported better color adjustment scores for multishade composites than omnichroma, for the assessments 48 h after the restorations. However, class III restorations were performed on acrylic dentures and different resin-based composites were examined compared to our study, which might be the reason for their controversial results. Additionally, according to our results, it might be interpreted that, the color adjustment potential of the EU composite was more stable among the others, whereas it was worse in time for the CDO. According to our results, all the restorations with three monoshade universal composites presented acceptable levels of color adjustments (AT ≤ 1.8), but above the perceptible limits (PT > 0.8).

Kobayashi et al. [4] observed that the background cavity color can affect the final shade of the restoration, depending on the translucency of the resin-based material used. Iyer et al. [23] observed a better color adjustment for omnichroma in lighter cavities, whereas better color matching for the multishade composites in darker cavities. Supporting these results, the restorations performed in B1 shade cavities presented significantly a better level of color adjustment compared to the A2 and C4 shades, respectively in this study ($p < 0.05$). The monoshade universal composites CDO and EU generally include an additional A2 shade which is the most common dental shade for most people, resulting in a potentially good color adjustment [1]. Additionally, many composite brands were reported to change color and get lighter after the polymerization procedure is completed [24–26]. Therefore, it is possible for both A2-pigmented CDO and EU, and also, the selected shades of NEO might have got lighter in time and matched better with the lighter cavity shades in our study [10]. This might be the reason that the level of color adjustment got worse from lighter cavities to darker cavities for all the composite groups, even for the control group performed with shade selection ($p < 0.05$). As explained previously, the unique optical properties of OMNI might be the reason for the better shifting ability in time. As a result, the second hypothesis of the study is rejected. However, the restoration borders were considered perceptible even in B1 shade cavities (Table 3).

This *in vitro* study has also limitations. Only three different monoshade universal composites were evaluated in this study. Different materials in different brands should be selected for further studies. Acrylic dentures might have affected the color adjustment potential of the composite materials as previously mentioned previously [4,27]. Thus, it might be more informative to perform the restorations in extracted human teeth or *in vivo* for further assessments. Further clinical investigations are necessary to understand and evaluate the color adjustment potential of these contemporary resin-based materials better.

5 Conclusion

Monoshade universal composites presented acceptable but perceptible color adjustment levels in class I cavities without shade selection. However, the adjustment was better for the restorations in lighter cavities. Better color adjustments were observed after the polymerization is completed. Therefore, better color adjustments were obtained after 24 h, and the best were obtained after 2 weeks for all the composites. At 2 weeks assessments, OMNI and EU presented better color adjustments than CDO. Simplyshade composites with a shade selection procedure might still be the best option to obtain a higher level of color adjustments for the restorations.

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Data availability statement: The statistical data used to support the findings of this study are available from "www.eistatistik.com" upon request.

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