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RESEARCH

Fluorescence and color adjustment potentials of paste-type and flowable resin composites in cervical restorations

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Abstract

Objective Comparatively assess the fluorescence and color adjustment potentials of paste-type and flowable resin composites performed in cervical restorations.

Materials and methods Five paste-type resin composites and 5 highly-filled flowable composites were investigated (n=5 for each). Class V cavities on 50 extracted A2 shade human central incisors were restored. Cross-polarization (CP) and fluorescence illumination (FI) images were recorded for each restoration. L*a*b* values were analyzed using the Photoshop software and color adjustment (ΔE_{CP}) and fluorescence adjustment (ΔE_{FI}) levels were quantitatively assessed. Kruskal Wallis Test, Independent Samples t Test, One Way Anova-Welch test, and Pearson Correlation were used for the statistical analyses. The deemed significance was set at $p<.050$.

Results Paste-type composites presented significantly lower ΔE_{FI} and ΔE_{CP} values than the flowable composites ($p=.006$ and $p<.001$ respectively). ΔE_{FI} and ΔE_{CP} values were positively correlated ($r=0.584$; $p<.001$). Paste-type Gaenial A'chord presented the lowest ΔE_{FI} value [7.67 (5.35 - 10.99)^{b}], while Estelite Asteria presented significantly the highest [19.94 (17.08 - 22.17)^{c}]. Charisma Diamond One Flow presented the highest ΔE_{CP} value [3.25 (3.13 - 3.39)^{a}] and Gaenial A'chord presented the lowest [0.79 (0.48 - 0.87)^{e}] which was the only imperceptible score (<0.8). The only clinically acceptable color adjustment was found for Geanial Universal Injectable [1.06 (0.73 - 1.62)^{e}] among the flowable composites. ΔE_{FI} and b* values were positively correlated ($r=0.493$; $p<.001$).

Conclusions Color adjustment level and fluorescence adjustment level were considered coherent for particular composite brands. At the same time, both were better for the paste-type composites than the flowable composites on A2 base shade class V restorations. Fluorescence adjustment potential as well as the color adjustment potential varied among different composite brands regarding paste-type and flowable composites.

Clinical significance Understanding both the color and fluorescence adjustment potentials of paste-type and flowable resin-based composite materials is clinically vital to achieve the high-end esthetics.

Keywords Color adjustment · Cross-polarization · Digital image analysis · Flowable · Fluorescence · Resin composite

Introduction

The concept of color adjustment potential (CAP) was introduced to describe and quantify the interaction between natural teeth and the restorative material [1]. The esthetic success of resin-based composite restorations depends on their ability to mimic the optical properties of natural teeth in different illuminations. Therefore, when selecting a resin-based restorative material, various optical properties such as light transmission, reflection, absorption, translucency, opalescence, and fluorescence must be considered to evaluate the level of esthetics clinically [2, 3]. Fluorescence is defined as the property of a substance to absorb and emit light at a longer wavelength when exposed to irradiation [4]. The fluorescence feature of natural dentin tissue exhibits approximately 3 times more than the enamel tissue due to its organic collagen composition [5].

Researchers emphasize the critical role of fluorescence as an optical attribute that can also influence the esthetic outcome of restorative treatment [6]. The type and composition of the resin-based composites play an important role in

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the fluorescence intensity [7]. That is due to the inclusion of luminescent additive elements in the resin composites such as ytterbium, cerium, europium, and terbium, which display visible fluorescence [8]. Although a similar fluorescence level is needed between the restorative material and the surrounding dental tissue to achieve natural-like restorations, a higher fluorescence level may also be demanded for some cases regarding resin remnant removal [4]. Accordingly, the fluorescence-aided identification technique (FIT) has been introduced to enhance the identification and differentiation of resin-based materials from natural tooth substances. It can aid in the removal of orthodontic brackets, attachments, trauma splints, and old resin-based composite restorations [9]. The FIT was determined to effectively reduce the iatrogenic removal of sound tooth structure during the resin remnant removal procedure [10].

Dental color can be evaluated using either visually or quantitatively. Challenges in esthetic restorative procedures often arise from color matching, predominantly relying on the visual analog approach [11]. Quantitative instrumental methods have been developed to alleviate objectivity issues in color registration, encompassing spectrophotometers, colorimeters, and digital camera kits. It was previously mentioned that digital imaging may offer more reliable color data in dentistry [12–14]. The currently preferred color formulation to assess the level of color adjustment is the CIEDE 2000 through the L*, a*, b* parameters. Threshold limits for clinical perceptibility (PT) and acceptability (AT) are ≥ 0.8 and <1.8 respectively [15, 16]. Recently, the b* parameter in the RGB color space was mentioned to exhibit the fluorescence level [17].

This in vitro study aimed to comparatively assess the fluorescence adjustment level (ΔE_{FI}) and color adjustment level (ΔE_{CP}) of 5 paste-type and 5 flowable resin-based composites which were layered in A2 base shade cervical restorations. The null hypotheses of the study were: (I) ΔE_{CP} and ΔE_{FI} are coherent regarding the composite materials, (II) different composite brands present similar ΔE_{CP} and ΔE_{FI}, (III) paste-type and flowable composites present similar ΔE_{CP} and ΔE_{FI}.

Materials and methods

The study protocol was approved by a local ethics committee (protocol number: 2023-153) and performed by the principles of the Declaration of Helsinki.

Teeth selection and restoration protocol

Human maxillary right and left central incisors which were extracted due to periodontal diseases were selected and kept in % 0.1 of thymol solution before the study. The selected teeth had no previous restorations, caries lesions, or hypomineralization lesions. The shade was measured using a contact-type spectrophotometer (Easyshade V, Vita, Germany) and only the teeth in A2 base shade were included (n=50) in the study. Identical cervical cavities were prepared on the vestibular surfaces by a single restorative dentistry instructor. Cavity preparations were performed under constant water cooling, by using green-band round-shape diamond burs which were renewed for every preparation (Acurata, Japan). The width of the cavities was 2 mm incisogingivally, 3 mm mesiodistally, and the gingival margin was 2 mm below the cemento-enamel junction. The depth of the cavities was 2 mm. 45° of bevelings were performed for the sharp enamel margins by using a chamfer bur. Following preparations the cavities were etched with 36% phosphoric acid and a universal adhesive agent (Prime&Bond Universal, Dentsply Sirona, USA) was applied per manufacturer's recommendations. Light curing was performed with a led curing unit (Valo Grand, Ultradent Products, USA) for 20 seconds. The radiant power of the Valo Grand light-curing unit used in this study was 1114 mW. The output was checked before the study by using a gold-standard spectroradiometer (MSC15-W, Gigahertz-Optik GmbH, Türkenfeld, Germany).

Five paste-type resin composites and five highly-filled flowable composites were selected for this study. The paste-type composites included a supra-nanohybrid monoshade universal composite (Omnichroma, Tokuyama, Japan), a supra-nanohybrid simplyshade composite (Estelite Asteria, Tokuyama), a nanohybrid simplyshade composite (G-aenial A'chord, GC Corp., Japan), a nanohybrid monoshade universal composite (Charisma Diamond One, Kulzer, Germany), and a nanohbrid simplyshade composite (Clearfil Majesty Es-II Universal, Kuraray, Japan). The flowable composites included a suprananohybrid monoshade universal composite (Omnichroma Flow, Tokuyama), a nanohybrid polyshade composite (Estelite Universal Flow, Tokuyama), a nanohybrid polyshade composite (G-aenial Injectable, GC Corp.), a nanohybrid monoshade universal composite (Charisma Diamond One Flow, Kulzer), and a nanohybrid polyshade composite (Clearfil Majesty LowFlow, Kuraray) (Table 1). The composites were layered in the cavities including the beveled surfaces with a single increment by using a restorative instrument (OptraSculpt Pad, Ivoclar Vivadent, Liechtenstein) and a composite brush (Compo Brush, Smile Line, USA) to avoid overcontouring. The restorations were cured again for 20 seconds for all the composites used. Surface polishing was performed with the diamond-embedded two-step spiral wheels (prepolisher and high-shine polisher, DiacompPlus Twist, EVE, Germany). Then all the teeth were kept in distilled water for one day before the evaluations and the next day repolished with the high-shine polisher spiral wheel.

Table 1 Manufacturer, composition, and classification of restorative materials

Resin Composite	Brand	Color	Manufacturer	Contents	Classification	Filler Ratio wt%/ vol%
Paste-Type	Omnichroma	U	Tokuyama Dental, Japan	UDMA, TEGDMA, Supra-nano spherical filler, round shaped composite filler (SiO_2, ZrO_2 260 nm)	Supranano hybrid, monoshade universal	79-68
	G-aenial A'chord	A2	GC, Japan	Bis-MEPP, Glass filler, organic filler (barium glass, silica)	Nano hybrid, simplyshade	82-65
	Estelite Asteria	A2B	Tokuyama, Japan	Bis-GMA, BisMEPP, TEGDMA, UDMA, 200 nm spherical SiO_2-ZrO_2 fillers	Supranano hybrid, simplyshade	82-71
	Clearfil Majesty ES-2	U	Kuraray, Japan	Bis-GMA, hydrophobic aromatic DMA and hydrophobic aliphatic DMA, camphorquinone, silanated barium glass (0.37–1.5 µm) and prepolymerised filler	Nano hybrid, polyshade	78-40
	Charisma Diamond One	U	Kulzer, Germany	TCD-üretanakrilat, UDMA, TEGDMA, barium aluminum boro floro silicate glass, 5 nm–20 µm fillers	Nano hybrid, monoshade universal	81-64
Flowable	Omnichroma Flow	U	Tokuyama Dental, Japan	UDMA, TEGDMA, Supra-nano spherical filler (200 nm spherical SiO_2-ZrO_2), round shaped composite filler (SiO_2, ZrO_2 260 nm)	Nanofilled, monoshade universal	71-n/a
	G-aenial Injectable	A2	GC, Japan	Bis EMA, UDMA Methacrylate monomer, Silica, barium glass (150 nm)	Nanohybrid, simplyshade	69-n/a
	Estelite Universal Flow	U	Tokuyama Dental, Japan	Bis-GMA, Bis-MPEPP, TEGDMA, UDMA, dl-camphoroquinone initiator, silica- zirconium, prepolymerised filler	Nanohybrid, simplyshade	70-56
	Clearfil Majesty Low Flow	U	Kuraray, Japan	TEGDMA, Hydrophobic aromatic dimethacrylate, Barium glass filler, Silica filler, dl-Camphorquinone, Photo initiator	Nanohybrid, monoshade	78-64
	Charisma Diamond One Flow	U	Kulzer, Germany	UDMA, EBADMA, Barium aluminium boro fluorine silicate glass, ytterbium fluoride, silicon dioxide, titanium dioxide	Nanohybrid, monoshade universal	n/a-41

Evaluation protocol

Two images were recorded for each restoration by using cross-polarization (CP) photography and fluorescence-illuminated (FI) photography techniques. The photography kit included a full frame DSLR camera (Nikon D750, Tokyo, Japan) and a macro-objective (105 mm Micro Nikkor, Nikon). CP photography was performed using a twin flash (R1C1, Nikon), a mount bracket (Owlbrckt C, Torun&Torun, Ankara, Türkiye) set at 45° angulation, and CP filters (Polar Eyes, Photomed, USA) (Fig. 1). The camera settings were set at f/22, ISO:400, 1/125. FI photography was performed using a PhotoBox (LIFE, China), in black color and dual fluorescence illumination lights (Valo Grand with black light lens, radiant power 218 mW) (Fig. 2). The camera settings were set at f/25, ISO:8000, 1/125.

The L*, a*, and b* color coordinates from the restoration and the adjacent natural dental tissue were measured using the info tab of the Photoshop CC software (Adobe Systems Inc., USA). Three measurements were performed from both the restoration and the adjacent natural dental tissue by a single operator to minimize bias. Quantitative ΔE_{00} values to assess color adjustment (ΔE_{CP}) and fluorescence adjustment (ΔE_{FI}) levels were generated using the CIEDE2000 formula. Additionally, the collected b* values in the RGB (red, green, blue) color space were used to evaluate the fluorescence adjustment level.

The statistical analyses were performed using SPSS statistics software program. The conformity to normal distribution was assessed using the Shapiro-Wilk and Kolmogorov-Smirnov tests. Data were statistically analyzed by Kruskal Wallis, Independent Sample *t*-test, One Way Anova-Welch test, and Pearson Correlation. The deemed significance was set at $< .050$.

Results

Regardless of the composite brand, paste-type composites presented significantly lower fluorescence adjustment (ΔE_{FI}) values compared to the flowable composites (p=.006). Also,

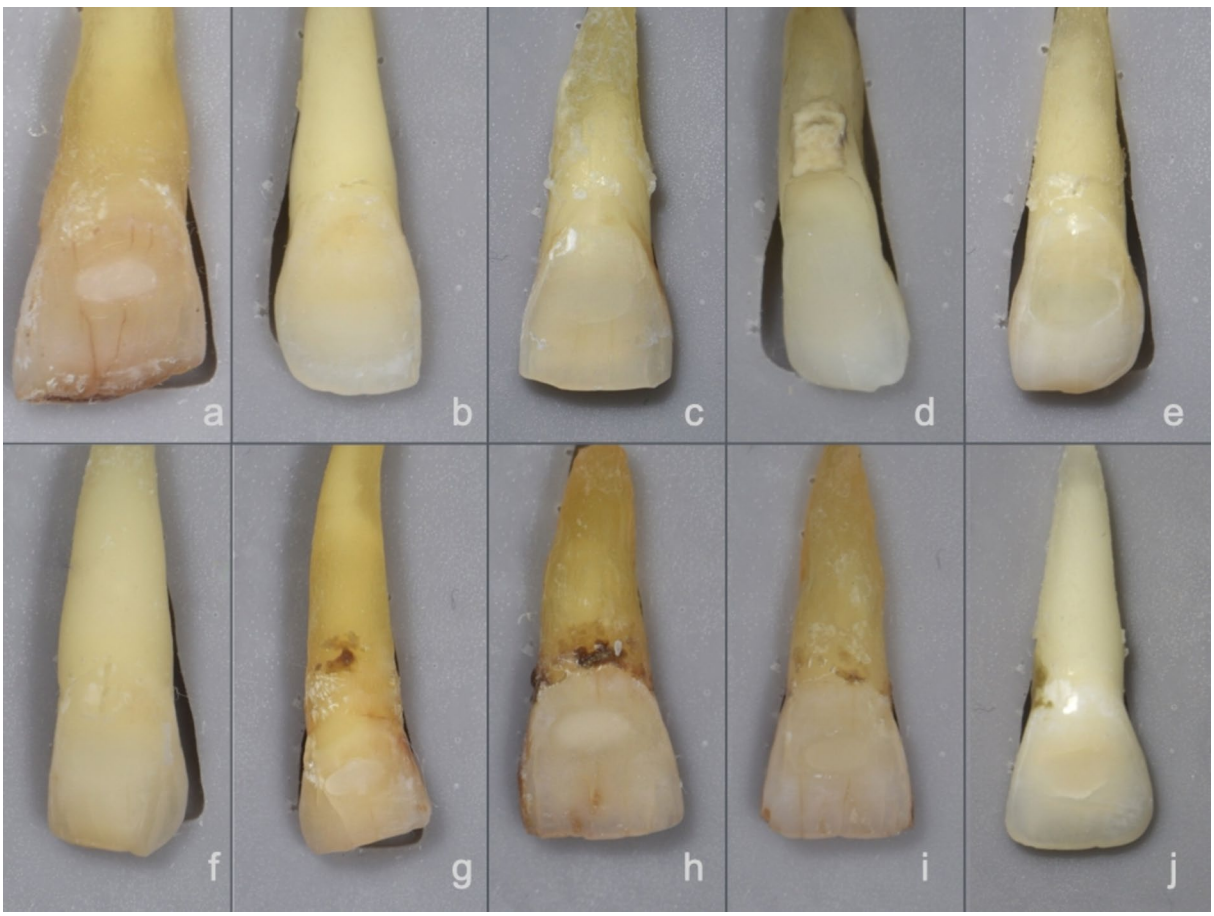

Fig. 1 Cross polarized photography for the composite brands. (**a**) Charisma Diamond One Flow (**b**) Clearfil Majesty LowFlow. (**c**) Estelite Universal Flow **d**) G-aenial Injectable. (**e**) Omnichroma Flow. (**f**) Charisma Diamond One. (**g**) Clearfil Majesty Es-II Universal. (**h**) Estelite Asteria. (**i**) G-aenial A'chord. (**j**) Omnichroma

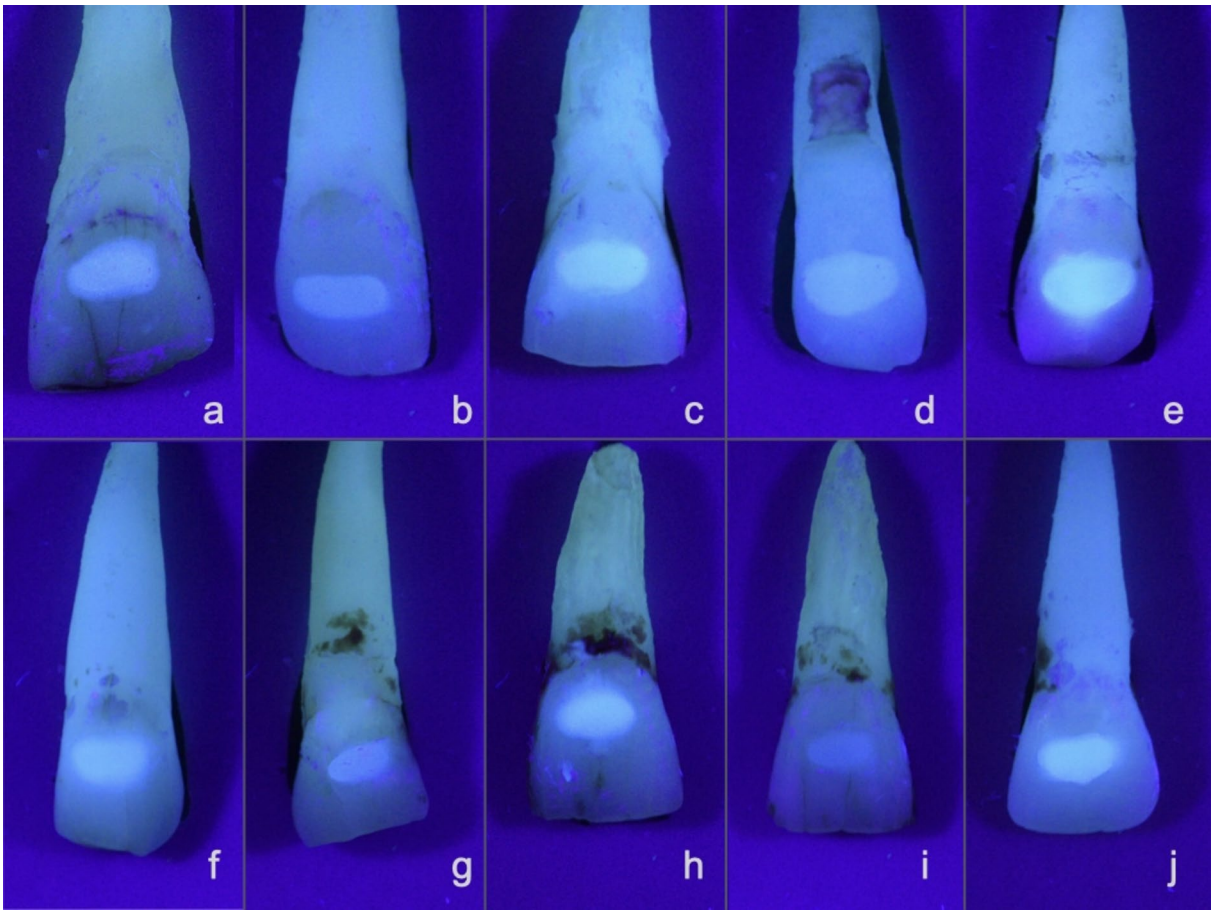

Fig. 2 Fluorescence-illuminated photography for each brand **a**) Charisma Diamond One Flow **b**) Clearfil Majesty LowFlow **c**) Estelite Universal Flow **d**) G-aenial Injectable **e**) Omnichroma Flow **f**) Charisma Diamond One **g**) Clearfil Majesty Es-II Universal **h**) Estelite Asteria **i**) G-aenial A'chord **j**) Omnichroma

paste-type composites presented significantly lower color adjustment (ΔE_{CP}) levels which were below the clinically acceptable threshold (1.8) compared to the flowable composites which were above the acceptable limit ($p<.001$) (Table 2).

Although the ΔE_{FI} and ΔE_{CP} values were positively correlated ($r=0.584$; $p<.001$), both varied significantly among the particular composite brands ($p<.001$ for each). Gaenial A'chord composite [7.67 (5.35 - 10.99)^{b}] presented the lowest ΔE_{FI} value and Clearfil Majesty Es II Universal [8.57 (3.60 - 13.22)^{b}] composite presented the second lowest value which two were also significantly lower than Estelite Asteria and Charisma Diamond One Flow composites ($p<.001$) (Table 3). No significant differences were found among the rest of the composite brands.

Gaenial A'chord composite [0.79 (0.48 - 0.87)^{e}] also presented the lowest ΔE_{CP} value and it was followed by Gaenial Injectable [1.06 (0.73 - 1.62)^{e}], Clearfil Majesty

Table 2 Comparison between paste-type and flowable composites regarding fluorescence adjustment (ΔE_{FI}) and color adjustment (ΔE_{CP}) values

	Composite Type				Test stat.	*P*
	Paste-Type		Flowable			
	Average ± sd	Median (min-max)	Average ± sd	Median (min-max)		
Fluorescence Adjustment	13.99 ± 4.52	15.29 (7.10 - 21)	18.20 ± 5.82	18.45 (8.70 - 32.7)	−2.858	**.006***
Color Adjustment	1.32 ± 0.54	1.19 (0.48 - 2.74)	2.24 ± 0.77	2.41 (0.73 - 3.39)	−4.930	**<.001***

*Independent Samples *t* Test

Table 3 Multiple comparisons of the composite brands regarding the fluorescence adjustment (ΔE_{FI}) and color adjustment (ΔE_{CP}) values

	Fluorescence Adjustment		Color Adjustment	
	Average ± sd	Median (min-max)	Average ± sd	Median (min-max)
Composite Brand				
Omnichroma	14.75 ± 2.08	15.10 (11.20 - 16.57)^{abc}	2.11 ± 0.49	2.21 (1.54 - 2.74)^{bc}
Gaenial A'chord	7.66 ± 2.25	7.67 (5.35 - 10.99)^{b}	0.75 ± 0.16	0.79 (0.48 - 0.87)^{e}
Estelite Asteria	19.52 ± 2.06	19.94 (17.08 - 22.17)^{c}	1.22 ± 0.35	1.26 (0.81 - 1.69)^{e}
Clearfil Majesty Es II	8.57 ± 3.56	8.57 (3.60 - 13.22)^{b}	1.14 ± 0.06	1.17 (1.03 - 1.19)^{e}
Charisma Diamond One	14.72 ± 3.25	14.68 (10.66 - 19.62)^{abc}	1.37 ± 0.33	1.51 (0.84 - 1.66)^{de}
Omnichroma Flow	17.40 ± 2.59	18.61 (13.05 - 19.19)^{abc}	2.67 ± 0.13	2.68 (2.47 - 2.80)^{ab}
Gaenial Universal Injectable	13.62 ± 3.19	13.76 (8.36 - 16.35)^{abc}	1.16 ± 0.38	1.06 (0.73 - 1.62)^{e}
Estelite Universal Flow	16.98 ± 2.47	16.58 (14.23 - 20.31)^{abc}	1.97 ± 0.42	1.85 (1.56 - 2.41)^{cd}
Clearfil Majesty Es II Flow	13.91 ± 2.89	13.90 (10.41 - 18.40)^{abc}	2.14 ± 0.26	2.19 (1.86 - 2.47)^{bc}
Charisma Diamond One Flow	20.39 ± 2.66	18.93 (18.03 - 23.28)^{ac}	3.26 ± 0.10	3.25 (3.13 - 3.39)^{a}
Test Statistics	34.613		169.580	
P	**<.001***		**<.001****	

*Kruskal Wallis Test; **One Way Anova-Welch test; a-c: No difference among the composite brands with the same letter

Es II Universal [1.17 (1.03 - 1.19)^{e}], Estelite Asteria [1.26 (0.81 - 1.69)^{e}], and Charisma Diamond One [1.51 (0.84 - 1.66)^{de}] with no significant difference among them ($p<.001$) (Table 3). All of these mentioned composites presented acceptable color adjustment (<1.8), while Gaenial A'chord presented also below the perceptible threshold (0.8). The rest of the composites presented unacceptable color adjustments (≥1.8).

Regarding the restoration b* values Gaenial A'chord presented quantitatively the lowest and also significantly lower value compared to the Charisma Diamond One Flow ($p=.006$) (Table 4). However, no significant differences were detected among the rest of the composite brands ($p\geq.050$). ΔE_{FI} and b* values were positively correlated ($r=0.493$; $p<.001$).

Discussion

The first hypothesis was accepted regarding a positive strong correlation between ΔE_{FI} and ΔE_{CP} values. The second hypothesis was rejected due to significant differences between ΔE_{CP} and ΔE_{FI} values in particular composite brands. The third research hypothesis was rejected concerning the observed lower ΔE_{CP} and ΔE_{FI} values for the paste-type composites than the flowable composites.

The color adjustment mechanism of resin-based composite materials relies on the surrounding intact natural dental tissue, which relates to the blending effect [18]. Numerous resin-based composite materials in the market were claimed to exhibit the blending effect [19, 20]. Regarding the composite shade assessment, various instruments such

Table 4 Comparison of RGB restoration b* values for fluorescence adjustment (ΔE_{FI}) of composite brands

	RGB Restoration b*		Test Statistics	*P**
	Average ± sd	Median (min-max)		
Composite Brand				
Omnichroma	247.87 ± 3.26	249 (243.33 - 251)^{ab}	22.943	**.006**
Gaenial A'chord	224 ± 20.99	228.33 (197 - 245.67)^{b}		
Estelite Asteria	251.47 ± 2.16	251 (249 - 254.67)^{ab}		
Clearfil Majesty Es II	232.80 ± 20.04	233.67 (202.33 - 251.33)^{ab}		
Charisma Diamond One	249.87 ± 4.92	253 (244 - 254)^{ab}		
Omnichroma Flow	245.13 ± 9.19	241.33 (236.33 - 255)^{ab}		
Gaenial Universal Injectable	246.67 ± 8.60	247 (235.67 - 255)^{ab}		
Estelite Universal Flow	252.13 ± 2.92	252.33 (249 - 255)^{ab}		
Clearfil Majesty Es II Flow	242 ± 10.04	246.67 (224.67 - 249)^{ab}		
Charisma Diamond One Flow	254.73 ± 0.43	255 (254 - 255)^{a}		

*Kruskal Wallis Test; a-b: No difference among the composite brands with the same letter

as spectrophotometers and colorimeters have been utilized to perform an objective analysis. Digital cameras, intra-oral scanners, and smartphones were also used as alternative tools [21].

Recently, digital image analysis with cross-polarizing (CP) filters has emerged as an objective and quantitative method for shade selection, and it was considered effective and accurate [22]. The CP filter may enhance the visibility of the underlying dentin shade and enamel characteristics, creating a chromatic map that naturally improves contrast [23]. Besides, it eliminates specular surface reflections that can lead to shade mismatches, thus providing a more standardized and uniform lighting on the tooth surface [18, 22]. Mahn et al [11], assessed the shade assessment methods for maxillary right central incisors of 60 volunteers in a clinical study and included the visual method, digital visual method with a CP filter, and a spectrophotometer [21, 24]. The spectrophotometer was previously considered the gold standard for dental shade determination [25, 26], and Mahn et al. [11] stated that the CP filter and spectrophotometer results were consistent. However, the spectrophotometer is only accurate for assessing natural dental tissues rather than restorative materials, due to the effect of unwanted light reflections and ambient light [11, 27, 28]. Numerous studies also supported the effectiveness of CP-filtered digital photography by considering it a prosperous tool for shade determination [12, 27, 29]. Accordingly, in the present study digital images provided by CP-filtered digital photography were used for the shade analyses.

Color adjustment of resin composite restorations is critical for clinical success, as ensuring that the restoration blends seamlessly with the natural tooth color is essential for esthetic purposes [28]. The color adjustment potential depends on the brand of the resin composite and the shade of the material [1]. Consistent with this, the Gaenial A'chord composite presented the lowest ΔE_{CP} value among the paste-type, and the Gaenial Injectable composite presented the lowest ΔE_{CP} among flowable composites. Different materials of the same brand exhibited similar CAP, whereas this was not valid for the other groups. Only Gaenial Injectable was below the acceptable threshold (<1.8) among the flowable composites and Gaenial A'chord was also below the perceptible threshold (0.8) among all. These results may be explained by the fact that the color and fluorescence adjustment characteristics of the resin-based restorative materials can be related as previously mentioned [30]. Gaenial A'chord and Gaenial Injectable composites have similar color adjustment and fluorescence adjustment levels in the present study.

Fluorescence characteristics were considered as crucial as color adjustment for achieving optimal esthetic outcomes in dental restorations [31]. In recent decades, there has been a growing interest among dental researchers in the fluorescence properties of tooth structure, influencing the development of new esthetic restorative materials that emit fluorescence. In this manner, various composite compositions of recent generations endeavor to emulate the inherent luminescence properties of dental tissue [32, 33].

To enhance the esthetics of composite materials under different lighting conditions, europium, ytterbium, or other rare-earth elements have been incorporated into glass fillers as fluorescent additives [34]. These elements are incorporated into glass fillers and they cause the excitation and emission to occur at different wavelength ranges. However, the restorative composite materials may have varying fluorescent potentials like the color adjustment potentials. Various fluorescent lights at different wavelengths (ranging between 350 to 400 nm) to evaluate the fluorescence potential of dental resin composites [35]. Meller and Klein [36] and da Silva et al [37], used 398 nm, Jablonski et al [38], Takahashi et al [39], used 380 nm, and Tavares et al [40], used 365 nm wavelengths for the evaluations. The fluorescence intensity tends to increase as the wavelength decreases and the spectrum of the excitation light becomes narrower around its highest level [6]. The limited scientific information in the literature about composite fluorescence indicates that 365 nm fluorescent light can be used to evaluate the fluorescent adjustment potential [30, 41].

In the dark environment, the dental fluorescence generated by the source of the fluorescent light illumination becomes more evident and thereby can be captured more easily by digital cameras [42]. This procedure allows for a more accurate fluorescence level assessment for the direct composite restorations. A PhotoBox (LIFE, China) was used in this study to obtain the best outcome for the images generated by the fluorescence photography technique.

The fluorescence intensity of resin composites was previously considered not only composite brand but also composite shade dependent [30, 38]. Cruz et al. [43] assessed restorations performed by 9 different resin composites (61 different shades). They observed significantly higher fluorescence for Spectra LV (Dentsply) than Filtek Supreme (3M), Enamel Plus HRI (Micerium), and Harmonize (Kerr). Significant differences in fluorescence were observed among particularly amber, opalescent amber, blue, clear, gray, opalescent blue natural, and pink opaquer, which exhibited notable variation compared to the other shades. Their results indicate that the fluorescence was significantly influenced by both the brand and the shade of the resin composite. They also stated that the brand has a greater impact on the fluorescence of resin composites than the shade or opacity. Even though the present study did not compare different shades, our results are consistent with the results of Cruz et al, as the ΔE_{FI} varied among the particular composite brands (Table 3). Additionally, this study inspected the monoshade universal composites like Omnichroma and Charisma

Diamond One regarding the ΔE_{FI} values for the first time in literature, and moderate ΔE_{FI} values for both materials were observed which were statistically similar to the simplyshade composites. However, Gaenial A'chord and Clearfil Majesty ES II Universal composites presented lower ΔE_{FI} values than the Estelite Asteria and Charisma Diamond One Flow composites which was consistent with the previous studies indicating variations in the fluorescence intensities of resin composites [7, 36, 38].

Even though it was previously reported that the color parameters such as fluorescence and opalescence may rely on various factors including the rate of composite fillers [30], the filler contents of the resin composites in this study varied and could not be the explanation for this observation (Table 1). However, the natural fluorescence attributes which aim to mimic the appearance of natural teeth under various lighting conditions, could be the answer for the results [44]. According to the results, especially the Gaenial A'chord composite could meet the expectations by providing the best fluorescence match to the natural tooth (Table 3). Additionally, monoshade universal composites did not present the best level of color and fluorescence adjustments, but only a moderate level (Table 3).

The exact mechanism underlying the fluorescence difference between flowable, and paste-type composite materials remains unclear [7]. Yu and Lee [7], evaluated the optical properties including color, translucency, and fluorescence of 4 different brands of flowable and paste-type composites in vitro. Significantly different optical properties were observed for flowable and paste-type resin composites and this was associated with the amount of light reflected from or within the resin composite material according to their report. This optical feature provides brightness and luminosity for restorative materials [45]. Consequently, the organic and inorganic composition and filler content of composites may play a role in fluorescence features [46]. The present study reports better fluorescence and color match values for the paste-type composites compared to the flowable composites which were in agreement with the previous results (Table 2).

Lim and Lee [30] evaluated the fluorescent emission of different shades of resin composites in vitro and investigated 8 resin composites and 41 different shades. They mentioned that the fluorescence emission is related to the chroma component of the material's color, and found a correlation between color difference and fluorescent peak height [37]. In this study ΔE_{FI} and ΔE_{CP} values were positively correlated consistent with the results of Lim and Lee [30]. The result can be attributed to the chroma level of the composite materials used. Lopes et al. [45] evaluated the fluorescence intensity of six resin composites and compared it to natural enamel, both in vitro and in vivo. For the in vitro part, the fluorescence intensity of disc-shaped resin specimens was assessed by three calibrated evaluators, through digital photographs like the present study. However, their assessments were visually unlike this quantitive study. According to their results, fluorescence adjustment potential varied among different composite brands which was in agreement with the results of this study. They also assessed cervical lesions clinically with a bulk-fill flowable composite and observed higher fluorescence than enamel [45]. This research observed the cervical restorations in vitro and this might be considered a limitation. Moreover, many previous in vitro studies using silicone molds or acrylic dentures may also have limitations in presenting color adjustment potential [28, 47]. The extracted central incisors with cervical restorations were used to avoid the dehydration effect in the present study to achieve the most realistic results.

There is limited clinical evidence regarding the utilization of the b* parameter in RGB color space for evaluating fluorescence properties [17, 41]. De Lima et al., [41] suggested a new methodology that the brighter pattern of the b* parameter could be used to assess the fluorescence properties. Similarly, Hirata et al, [17] assessed the translucency and fluorescence parameters of 5 different resin composites in vitro and used the b* parameter to evaluate the fluorescence intensity of restorative materials through digital photography. This methodology provided a basis for comparing the fluorescence measurements across various studies. Consistent with the previous findings, in this study, both the b* parameter and ΔE_{FI} values were found coherent. Nevertheless, further clinical and laboratory investigations regarding the b* parameter would be beneficial for clinical practice in deciding the fluorescence level of restorative materials.

The thickness of the resin composite might be one of the factors influencing the translucency, while the depth of the cavity as well as the thickness of the material were not evaluated in this study. Only the body shades of simplyshade composites were assessed, however, enamel and dentin shades in different opacity and chroma were not evaluated. It might be always more realistic to subject the materials to an artificial aging process in vitro before the shade evaluation. Clinical studies might be beneficial to better understand the color and fluorescence adjustments of the materials and to guide the clinicians in restorative practice.

Conclusion

Within the limitations of this in-vitro study, color adjustment and fluorescence adjustment potentials were considered better for the paste-type composites compared to the flowable composites. Therefore, it might be better to select paste-type composites for patients with high esthetic expectations. Whereas, color and fluorescence adjustment findings were positively correlated. Gaenial A'chord composite was

considered the best resin composite material among all for fluorescence match and also the only one with the imperceptible color match. Gaenial Universal injectable presented the best fluorescence and color match values among the flowable composites. The b* parameter of the RGB color space can be determined as a potentially useful tool for assessing the fluorescence level of composite materials.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00784-024-06054-x.

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Declarations

Ethics approval The study protocol was approved by the Ethics Committee of the Marmara University Faculty of Dentistry (protocol number: 2023-153), and it is certified that the study was conducted in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

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References

1. Trifkovic B, Powers JM, Paravina RD (2018) Color adjustment potential of resin composites. Clin Oral Investig 22:1601–1607. https://doi.org/10.1007/s00784-017-2260-6
2. Paravina RD, Westland S, Johnston WM, Powers JM (2008) Color adjustment potential of resin composites. J Dent Res 87:499–503. https://doi.org/10.1177/154405910808700515
3. Paravina RD (2009) Critical appraisal. Color in dentistry: match me, match me not. J Esthet Restor Dent 21:133–139. https://doi.org/10.1111/j.1708-8240.2009.00246.x
4. Kiran R, Chapman J, Tennant M, Forrest A, Walsh LJ (2020) Fluorescence-aided selective removal of resin-based composite restorative materials: An in vitro comparative study. J Esthet Restor Dent 32:310–316. https://doi.org/10.1111/jerd.12536
5. Mualla SK (2016) Fluorescence and dentistry. J Dent Med Sci 15:65–75
6. Brokos I, Stavridakis M, Lagouvardos P, Krejci I (2021) Fluorescence intensities of composite resins on photo images. Odontology 109:615–624. https://doi.org/10.1007/s10266-020-00583-z
7. Yu B, Lee Y-K (2008) Differences in color, translucency and fluorescence between flowable and universal resin composites. J Dent 36:840–846
8. Pereira JSC, Reis JA, Martins F, Maurício P, Fuentes MV (2022) The Effect of Feldspathic Thickness on Fluorescence of a Variety of Resin Cements and Flowable Composites. Appl Sci 12:6535
9. Klein C, Wolff D, Ohle CV, Meller C (2021) The fluorescence of resin-based composites: An analysis after ten years of aging. Dent Mater J 40:94–100. https://doi.org/10.4012/dmj.2019-320
10. Klein C, Babai A, von Ohle C, Herz M, Wolff D, Meller C (2020) Minimally invasive removal of tooth-colored restorations: evaluation of a novel handpiece using the fluorescence-aided identification technique (FIT). Clin Oral Investig 24:2735–2743. https://doi.org/10.1007/s00784-019-03135-0
11. Mahn E, Tortora SC, Olate B, Cacciuttolo F, Kernitsky J, Jorquera G (2021) Comparison of visual analog shade matching, a digital visual method with a cross-polarized light filter, and a spectrophotometer for dental color matching. J Prosthet Dent 125:511–516. https://doi.org/10.1016/j.prosdent.2020.02.002
12. Lakhanpal S, Neelima MS (2016) Accuracy of Three Shade-matching Devices in Replicating the Shade of Metal Ceramic Restorations: An in vitro Study. J Contemp Dent Pract 17:1003–1008
13. Igiel C, Lehmann KM, Ghinea R, Weyhrauch M, Hangx Y, Scheller H, Paravina RD (2017) Reliability of visual and instrumental color matching. J Esthet Restor Dent 29:303–308. https://doi.org/10.1111/jerd.12321
14. Tabatabaian F, Beyabanaki E, Alirezaei P, Epakchi S (2021) Visual and digital tooth shade selection methods, related effective factors and conditions, and their accuracy and precision: A literature review. J Esthet Restor Dent 33:1084–1104
15. Paravina RD, Pérez MM, Ghinea R (2019) Acceptability and perceptibility thresholds in dentistry: A comprehensive review of clinical and research applications. J Esthet Restor Dent 31:103–112. https://doi.org/10.1111/jerd.12465
16. Pérez MM, Ghinea R, Herrera LJ, Carrillo F, Ionescu AM, Paravina RD (2018) Color difference thresholds for computer-simulated human Gingiva. J Esthet Restor Dent 30:E24–E30. https://doi.org/10.1111/jerd.12373
17. Hirata R, Benalcázar-Jalkh E-B, Atria P, Cascales Á-F, Cantero J-S, Sampaio C-S (2024) Analysis of translucency parameter and fluorescence intensity of 5 resin composite systems. J Clin Exp Dent 16:e71
18. Yamanel K, Caglar A, Ozcan M, Gulsah K, Bagis B (2010) Assessment of color parameters of composite resin shade guides using digital imaging versus colorimeter. J Esthet Restor Dent 22:379–388. https://doi.org/10.1111/j.1708-8240.2010.00370.x
19. Ikeda T, Sidhu SK, Omata Y, Fujita M, Sano H (2005) Colour and translucency of opaque-shades and body-shades of resin composites. Eur J Oral Sci 113:170–173
20. Yılmaz Atalı P, Doğu Kaya B, Manav Özen A, Tarçın B, Şenol AA, Tüter Bayraktar E, Korkut B, Bilgin Göçmen G, Tağtekin D, Türkmen C (2022) Assessment of micro-hardness, degree of conversion, and flexural strength for single-shade universal resin composites. Polymers 14:4987
21. Gurrea J, Gurrea M, Bruguera A, Sampaio CS, Janal M, Bonfante E, Coelho PG, Hirata R (2016) Evaluation of Dental Shade Guide Variability Using Cross-Polarized Photography. Int J Periodontics Restorative Dent 36:e76–e81. https://doi.org/10.11607/prd.2700
22. Hein S, Modrić D, Westland S, Tomeček M (2021) Objective shade matching, communication, and reproduction by combining dental photography and numeric shade quantification. J Esthet Restor Dent 33:107–117

23. Ra'fat IF, Almershed AS, Albahli BF, Ali SNA-H (2022) Effect of ambient lighting conditions on tooth color quantification in cross-polarized dental photography: A clinical study. J Prosthet Dent 128:776–783
24. Sampaio CS, Gurrea J, Gurrea M, Bruguera A, Atria PJ, Janal M, Bonfante EA, Coelho PG, Hirata R (2018) Dental Shade Guide Variability for Hues B, C, and D Using Cross-Polarized Photography. Int J Periodontics & Restorative Dent
25. Suganya SP, Manimaran P, Saisadan D, Kumar CD, Abirami D, Monnica V (2020) Spectrophotometric evaluation of shade selection with digital and visual methods. J Pharm BioAllied Sci 12:S319–S323
26. Korkut B (2024) Composite Restorations in Anterior Esthetics. Quintessence Publishing, Germany
27. Sampaio CS, Atria PJ, Hirata R, Jorquera G (2019) Variability of color matching with different digital photography techniques and a gray reference card. J Prosthet Dent 121:333–339
28. Korkut B, Hacıali Ç, Tüter Bayraktar E, Yanıkoğlu F (2023) The assessment of color adjustment potentials for monoshade universal composites. Sci Eng Compos Mater 30:20220189
29. Saygılı S, Albayrak B, Sülün T (2024) Effect of different instrumental techniques and clinical experience on shade matching. J Prosthodont
30. Lim YK, Lee YK (2007) Fluorescent emission of varied shades of resin composites. Dent Mater 23:1262–1268. https://doi.org/10.1016/j.dental.2006.11.022
31. Kim HK (2020) Optical and Mechanical Properties of Highly Translucent Dental Zirconia. Materials 13. https://doi.org/10.3390/ma13153395
32. Jum'ah AA and Brunton PA (2023) Bulk-Fill Resin Composites: Recent Advances and Future Perspectives. Bulk Fill Resin Composites in Dentistry: A Clinical Guide:159-177.
33. Fondriest J (2003) Shade matching in restorative dentistry: the science and strategies. Int J Periodontics Restorative Dent 23:467–479
34. Uo M, Okamoto M, Watari F, Tani K, Morita M, Shintani A (2005) Rare earth oxide-containing fluorescent glass filler for composite resin. Dent Mater J 24:49–52. https://doi.org/10.4012/dmj.24.49
35. Tonetto MR, De Oliveira O, De Campos EA, Saad JRC, Dantas AAR, de SouzaRastelli AN, Neto S, de Adrade M (2012) Fluorescence level of composites assessed by computer processing of digital images: ScanWhite©. World J Dent 3:141–144
36. Meller C, Klein C (2015) Fluorescence of composite resins: A comparison among properties of commercial shades. Dent Mater J 34:754–765
37. Da Silva RD, da Silva MAD, de Oliveira OB, Melo ACM, de Oliveira RN (2013) Dental fluorescence: potential forensic use. Forensic Sci Int 231:167–171
38. Jablonski T, Takahashi MK, Brum RT, Rached RN, Souza EM (2014) Comparative study of the fluorescence intensity of dental composites and human teeth submitted to artificial aging. Gen Dent 62:37–41
39. Takahashi MK, Vieira S, Rached RN, Almeida Jd, Aguiar M, Souza Ed (2008) Fluorescence intensity of resin composites and dental tissues before and after accelerated aging: a comparative study. Oper Dent 33:189–195
40. Tavares C, Tavares L, Correia A, Bresciani E, Caneppele T (2016) Effect of thickness on fluorescence of resin-composites and dental substrates. Braz Dent Sci 19:53–58
41. Meller C, Klein C (2012) Fluorescence properties of commercial composite resin restorative materials in dentistry. Dent Mater J 31:916–923. https://doi.org/10.4012/dmj.2012-079
42. Conceição LD, Masotti AS, Forgie AH, Leite FRM (2019) New fluorescence and reflectance analyses to aid dental material detection in human identification. Forensic Sci Int 305:110032
43. Cruz J, Eira R, Coito C, Sousa B, Cavalheiro A (2024) Fluorescence of Esthetic Resin Composites: Spectrophotometry and Photography Analysis Techniques. Eur J Dent 18:485–492
44. Volpato CAM, Pereira MRC, Silva FS (2018) Fluorescence of natural teeth and restorative materials, methods for analysis and quantification: A literature review. J Esthet Restor Dent 30:397–407
45. Lopes GM, Prado TP, Camilotti V, Bernardon P, Mendonça MJ, Ueda JK (2021) In Vitro and in vivo evaluation of resin composites fluorescence. J Mech Behav Biomed Mater 114:104223
46. Tabatabaei MH, Nahavandi AM, Khorshidi S, Hashemikamangar SS (2019) Fluorescence and opalescence of two dental composite resins. Eur J Dent 13:527–534
47. Korkut B, Tarçın B, Atalı PY, Özcan M (2023) Introduction of a New Classification for Resin Composites with Enhanced Color Adjustment Potential. Curr Oral Health Rep 10:223–232

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