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EFFECT OF CAVITY DIMENSIONS ON COLOR ADJUSTMENT OF SINGLE-SHADE VERSUS MULTI-SHADE RESIN COMPOSITE RESTORATIONS: *AN IN VITRO STUDY*

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ABSTRACT

Aim: To assess the effect of different cavity dimensions on the color adjustment potential of single-shade resin composite with or without blocker versus multi-shade resin composite.

Materials and methods: 120 class V cavities were prepared with the following dimensions: Group 1 (G1): mesio-distally = 3 mm, occluso-gingivally = 2 mm, depth = 1.5 mm, Group 2 (G2): mesio-distally = 3 mm, occluso-gingivally = 1.5 mm, depth = 2 mm, Group 3 (G3): mesio-distally = 3 mm, occluso-gingivally = 2 mm, depth = 2 mm, Group 4 (G4): mesio-distally = 3 mm, occluso-gingivally = 2 mm, and depth = 2.5 mm. Color assessment was done using VITA Easyshade® V. Three restorative materials were used: PALFIQUE OMNICHROMA BLOCKER (Tokuyama Dental Corporation, Japan) [B], PALFIQUE OMNICHROMA (Tokuyama Dental Corporation, Japan) [O], 3M™ Filtek™ Z350 XT Universal Restorative (3M ESPE Dental Products, USA) [Z]. The total color difference between the teeth and restorations was expressed by ΔE. All restorations were subjected to 10,000 thermal cycles. One way ANOVA, Bonferroni post hoc, paired t test, and Multiple ways ANOVA tests were used to analyze the results statistically.

Results: G4 recorded the highest mean value, followed by G3, then G1, with the lowest mean value in G2. Regarding subgroups: subgroup "B" recorded the highest value, followed by subgroup "O", then subgroup "Z", with a significant difference between the subgroups (p=0.00). Regarding thermocycling, a significantly higher mean value was recorded after thermocycling.

Conclusions: Increasing the cavity size and depth decreases the color adjustment of the restorative material.

KEYWORDS: Cavity depth – Cavity size - Color Adjustment - Single-Shade Resin Composite - Multi-Shade Resin Composite

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INTRODUCTION

Individuals' satisfaction with their teeth appearance is a fundamental aspect of human social interactions, resulting in improved psychological well-being and a better quality of life [1,2]. The accelerating pursuit of an esthetic smile in modern societies has increased the expectations and demands for esthetic tooth-colored restorations[3–5]. Dental resin composites are becoming the restorative materials of choice for most anterior and posterior restorations in daily practice [6–8]. They can be applied for a wide range of indications, such as direct and indirect restorations, diastema closure, core build-up, etc [9]. Resin composites are widely used because they provide excellent esthetics, optimal mechanical properties, acceptable durability, and feasible cost, in addition to a more conservative restorative approach in comparison to other tooth-colored restorative materials such as ceramics [10,11].

Proper restoration of tooth form, function, occlusion, and esthetics is a primary objective when restoring missing tooth structure [12]. The shape, size, and optical properties of tooth-colored restorations should ideally be in harmony with neighboring teeth [13]. An imperceptible match between the color of the restorative material and that of the tooth is paramount to achieving an excellent esthetic outcom[e] [14]. The polychromatic nature of natural teeth makes exact shade determination a challenge for the esthetic dentist, especially in restoring extensive cavities [12,15]. Tooth color varies in all directions: from occlusal/incisal to gingival, buccal/labial to lingual/palatal, and mesial to distal, and it mainly originates from the color of the dentin and the translucency, scattering, and thickness of the enamel [13,16]. The shades of the commercially available resin composites are usually labelled following the VITA classical shade system. They are marketed in different enamel, dentin, body, and opaque shades to simulate the color of tooth structures [17,18]. However, one of the limitations of resin composites is the incompatibility of their shades to those they are designated to match [19]. In addition to this, using these variable shades makes shade matching a complicated and time-consuming procedure [20].

It was noticed that the observed clinical color differences between resin composite restorations and surrounding teeth are less than those anticipated when viewing the colors separately. It was also observed that some tooth-colored restorative materials reflected the color of surrounding tooth structures, resulting in improved esthetic performance of the restorations after placement [10,21–23]. This phenomenon is described as the "chameleon effect" by clinicians and dental manufacturers [24]. The 'chameleon effect' is supposed to be due to the color blending of resin composites, which is related to the color reflection from surrounding tooth [10]. The term "chameleon effect" is usually used in psychology rather than color research [25]. In dental parlance, the terms "color adjustment", "color blending", "color assimilation", "color induction" were interchangeably used to name this phenomenon[12,16,26–28] Several factors were reported to affect the extent and direction of this color adjustment phenomenon: the size[26] and thickness of the restoration[24], resin composite's shade and type, and the amount of color difference between the restoration and the tooth [21,25] Based on this color adjustment concept, manufacturers have introduced "universal shade" or "single shade" resin composites, which are designed to esthetically mimic all VITA shades with only one nominal shade [29]. This would provide a valuable tool for clinicians to simplify restorative procedures [30].

Assessing tooth shade can be done visually or instrumentally. Visual evaluation is commonly used in clinical conditions, utilizing the color shade guides available by the manufacturers of restorative materials. The visual method can be easily applied by clinicians, but it is highly subjective and lacks precision and accuracy because many factors can affect color perception. These factors include, for example background colors, gingiva color and surrounding lighting conditions [31]. The assessor's age, gender, anxiety, mood, and drugs/medications can also influence color perception [15,31]. In contrast, instrumental methods (e.g., spectrophotometers, colorimeters) are objective, more accurate, and more consistent (5). No gold standard color measurement tool exists. Each instrument has its pros and cons. Generally, spectrophotometers are considered the most reliable and accurate color measurement tool (2). Spectrophotometers measure the spectral composition of the reflected light by the tooth at 1–25nm intervals within the visible spectrum and convert it into quantifiable data [32,33]. They are in compliance with the standard viewing and illumination parameters set by the *Commission Internationale de I'Eclairage* (CIE, International Commission on Illumination) [18]. Spectrophotometers display the results as L*, a*, and b* values [34]. Despite, different methodologies have been proposed in the literature for color matching assessment, the analysis of color differences ΔE parameter with the CIELAB formula (International Color Association, L* a* b*) was the most commonly used method [2,14].

In 2019, a universal resin composite OMNICHROMA (Tokuyama Dental Corporation, Taitou-Ku, Tokyo, Japan) was introduced into the market formulated on a "wide color matching" concept and available in one shade only. According to the manufacturer, it has the ability to match all 16 Vita Classical shades (Vita, Vita Zahnfabrik, BadSäckingen, Germany) so it can mimic the color of the surrounding tooth, regardless of its shade [35–37] . This unique ability was attributed to the inclusion of spherical zirconium dioxide (ZrO_2) and silicon dioxide (SiO_2) fillers with uniform size of 260 nm in the resin matrix, which could produce a red-to-yellow color [14,38]. The use of OMNICHROMA minimizes shade selection, simplifies clinical protocols, and reduces chair-side time [18]. Recently, a light cured radiopaque resin composite material, OMNICHROMA BLOCKER (Tokuyama Dental Corporation, Tokyo, Japan) was launched by the same manufacturer of OMNICHROMA. According to the manufacturer's recommendations, OMNICHROMA BLOCKER can be used in combination with OMNICHROMA resin composite or other resin composites to restore carious cavities of all classes. It can also be used to mask moderate discoloration regardless of the color of the restored tooth [39]. However, the available data for this recently marketed restorative material are lacking and more laboratory studies are mandatory. Therefore, this study was conducted to assess the instrumental color adjustment potential of single-shade resin composite with or without blocker versus multi-shade resin composite when applied in class V restorations with different sizes and depths in human maxillary premolar teeth. The three null hypotheses tested in this study were that there would be no differences in color adjustment (1) between the three restorative materials, (2) between restorations with different depths and sizes, and (3) before and after thermocycling.

MATERIALS AND METHODS

The color adjustment of three resin composite restorative materials was assessed and compared. PALFIQUE OMNICHROMA BLOCKER (Tokuyama Dental Corporation, Tokyo, Japan), PALFIQUE OMNICHROMA (Tokuyama Dental Corporation, Tokyo, Japan), and 3M™ Filtek™ Z350 Universal Restorative (3M ESPE Dental Products, MN, USA) were used in the present study. The restorative materials and their specifications, composition, shade, lot number, and manufacturers are described in table (1).

The protocol and the ethical issues of the study were revised by the Council of Conservative Dentistry Department and the Research Ethics Committee, Faculty of Dentistry, October 6 University on March 2nd, 2022 (Approval No. RECO6U/11-2022).

TABLE (1) Materials investigated in the study and their specification, composition, shade, lot number, and manufacturers

Material	Abbreviation	Specification	Resin matrix	Filler type	Filler loading		Shade	Lot Number	Manufacturer
					Wt.%	Vol%			
PALFIQUE OMNICHROMA BLOCKER	B	Shade-blocker resin composite	Bis-GMA, TEGDMA	Silica zirconia filler and composite filler.	82	71	-	34522	Tokuyama Dental Corporation, Tokyo, Japan
PALFIQUE OMNICHROMA	O	Single-shade resin composite	UDMA, TEGDMA	spherical silica zirconia filler and composite filler	79	68	-	209S2	Tokuyama Dental Corporation, Tokyo, Japan
3M™ Filtek™ Z350 XT Universal Restorative	Z	Multi-shade resin composite	Bis-GMA, UDMA, TEGDMA, Bis-EMA, PEGDMA	non-agglomerated/non aggregated silica filler, nonagglomerated/ non-aggregated zirconia filler, and aggregated zirconia/ silica cluster filler	78.5	63.3	A2 **Body Shade**	NA41179	3M ESPE Dental Products, MN, USA

*Abbreviations**: UDMA: Urethane dimethacrylate, TEGDMA: Triethylene glycol dimethacrylate, Bis-GMA***: Bisphenol A glycidyl methacrylate, Bis-EMA: Bisphenol A polyethylene glycol diether dimetacrylate. PEGDMA: polyethylene glycol dimethacrylate***

Teeth collection

Based on the results of a pilot study conducted by the authors, sample size was determined as a total of 120 teeth (10 teeth per group) using (α) level of 5%, (β) level of 20% (Power = 80%). G*Power version 3.1.9.2 was used for sample size calculation. Human maxillary premolar teeth of A2 shade with nearly similar buccopalatal and mesiodistal dimensions without restoration or endodontic treatment were used in this study. The teeth were extracted for orthodontic reasons from patients ranging from 19 to 37 years old after acquiring their informed consent. All teeth were cleaned from blood, saliva, soft-tissue debris and/or calculus deposits. Then, any tooth with visible cavities, or structural defects was discarded and replaced. Teeth were fixed in self-curing acrylic resin (Acrostone Cold Cure, Acrostone, Cairo, Egypt), displaying only the coronal part of the teeth to allow easy handling.

Assessment of teeth color

Instrumental color assessment of the teeth was carried out using a digital spectrophotometer, the VITA Easyshade® V (VITA Zahnfabrik, Bad Säckingen, Germany). The device was adjusted according to the manufacturer's instructions before use and after every three measurements. The probe tip was perpendicularly flushing with the center of the cervical third of the buccal surface. The shade of teeth (A2) was assessed, then the mean L*, a*, and b* values were recorded after the measurements were repeated three times. The L* vertical parameter refers to the lightness, which is represented on a scale from 0 (black) to 100 (white), while a* and b* color coordinates are chromatic axes in the red (+)/green (−) and yellow (+)/blue (−) direction, respectively [40].

Cavity preparations

Standardized class V cavities were prepared in the buccal surfaces of the teeth by the same operator. The teeth were divided into four groups according to the dimensions of the prepared cavities as follows:

Group 1 (G1): mesio-distally = 3 mm, occluso-gingivally = 2 mm, and depth = 1.5 mm. (Volume = 9 mm^3)

Group 2 (G2): mesio-distally = 3 mm, occluso-gingivally = 1.5 mm, and depth = 2 mm. (Volume = 9 mm^3)

Group 3 (G3): mesio-distally = 3 mm, occluso-gingivally = 2 mm, and depth = 2 mm. (Volume = 12 mm^3)

Group 4 (G4): mesio-distally = 3 mm, occluso-gingivally = 2 mm, and depth = 2.5 mm. (Volume = 15 mm^3)

To standardize the dimensions of cavity preparations, a rubber index was made with the abovementioned depths and sizes for each group to mark the outline of the cavity. After preparation, further checking was done by a digital caliper (Aluminum Caliper 4", IOS Ortho, Stafford, USA). Each cavity was prepared by #56 fissure bur (Komet®, Gebr. Brasseler GmbH & Co. Lemgo, Germany). A 45° bevel was prepared at the margin of occlusal wall. A new bur was used after every five cavities prepared to ensure efficient cutting.

Restorative procedures

The cavities were rinsed then dried by blotting. A one-component, one-coat, self-etching, light cured dental bonding system; PALFIQUE BOND (Tokuyama Dental Corporation, Tokyo, Japan) was applied. The bonding system was applied by a disposable applicator, air dried for 5 seconds using an oil-free air/water syringe by applying mild air continuously until the runny PALFIQUE BOND stayed in the same position without any movement, and then light cured for 10 seconds by a LED light curing unit (Dr's light AT CL-AT24, Good Doctors Co., Incheon, Republic of Korea) with a light intensity of 1400 mW/cm^2 and wavelength of 400–490 nm.

The groups were subdivided into three subgroups (n = 10) according to the type of restorative material; *Subgroup (B)*: PALFIQUE OMNICHROMA BLOCKER was applied to the walls of the prepared cavity in 0.5mm thickness then cured for 10 seconds. PALFIQUE OMNICHROMA was then applied to restore the cavity and cured for 10 seconds, *Subgroup (O)*: PALFIQUE OMNICHROMA was used only to restore the prepared cavity, *Subgroup (Z)*: 3M™ Filtek™ Z350 XT Universal Restorative was applied and cured for 20 seconds. After curing, the restorations were polished with fine (24µm) and superfine (8µm) Al_2O_3 discs (Sof-Lex™ discs, 3M ESPE Dental Products, MN, USA) for 20 seconds.

Color assessment of restorations

After storage at 37° C in deionized water for 24 hours, color assessment of the restorations was carried out in the same manner as done for the teeth. The total color difference between the teeth and restorations was expressed by ΔE using the following equation: [12,13,41]

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{½}$$

Delta-E Calculator (*http://colormine.org/delta-e-calculator*) was used for the calculation of ΔE values.

Thermocycling

All restorations were thermocycled between 5° C and 55° C with a dwell time of 30 seconds for 10,000 cycles using THE-1100 Thermocycler (SD Mechatronik, Feldkirchen-Westerham, Germany). After thermocycling, the color of the restorations was reassessed, and the total color difference was calculated in the same manner as done before thermocycling.

Statistical analysis

The Statistical Package for Social Sciences (SPSS) version 20 was used for statistical analysis of the results. Numerical data were summarized using mean, standard deviation, median and range. Data were explored for normality by checking the data distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Comparisons between groups and subgroups with respect to the normally distributed numeric variable (color change) was performed using one way analysis of variance ANOVA test, followed by Bonferroni post hoc test for pairwise comparison. Observations before and after thermocycling were compared using paired t-test. Multiple ways ANOVA test was used to study the effect different variables and their interaction. All p-values are two-sided. P-values ≤0.05 were considered significant.

RESULTS

Effect of restorative material

In group 1, before thermocycling, the mean value recorded in subgroup "B" (5.71±0.57), was significantly higher than the two other subgroups "O" (4.13±0.81) and "Z" (3.58±0.68) (p=0.00). After thermocycling, the mean values recorded in subgroups "B" (6.24±0.60) and "O" (5.68±1.31) were significantly higher than that of subgroup "Z" (4.14±0.66) (p=0.003).

In group 2, before thermocycling, there was no significant difference between the three subgroups: "B" (4.63±1.00), "O" (3.43±1.03), and "Z" (3.97±1.10) (p=0.171). After thermocycling, the mean value recorded in subgroup "B" (5.96±0.66) was significantly higher than the two other subgroups, "O" (4.09±1.03) and "Z" (4.54±1.14) (p=0.011)

In group 3, before thermocycling, the mean values recorded in subgroups "B" (5.29±0.51) and "O" (5.35±0.57) were significantly higher than that of subgroup "Z" (4.07±0.52) (p=0.001). After thermocycling, the mean values recorded in subgroups "B" (6.22±0.58) and "O" (5.97±0.67) were significantly higher than that of subgroup "Z" (5.08±0.54) (p=0.012).

In group 4, before thermocycling, the mean values recorded in subgroups "B" (6.00±0.68) and "O" (6.14±0.68) were significantly higher than subgroup "Z" (4.96±0.55) (p=0.011). After thermocycling, the mean value recorded in subgroup "B" (7.59±0.81) was significantly higher than the two other subgroups, "O" (6.46±0.80) and "Z" (6.55±0.78) (p=0.049).

Effect of restoration depth and size

In subgroup "B", before thermocycling, the mean value recorded in group 4 (6.00±0.68), was significantly higher than that of group 2 (4.63±1.00) (p=0.019). After thermocycling, the mean value recorded in group 4 (7.59±0.81) was significantly higher than all other groups (p=0.002).

In subgroup "O", before thermocycling, the mean values recorded in groups 4 (6.14±0.68) and 3 (5.35±0.57), were significantly higher than those in group 1 (4.13±0.81) and 2 (3.43±1.03) (p=0.00). After thermocycling, the mean value recorded in group 4 (6.46±0.80) was significantly higher than all other groups (p=0.003).

In subgroup "Z", before thermocycling, the mean value recorded in group 4 (4.96±0.55) was significantly higher than group 1 (3.58±0.68) (p=0.03). After thermocycling, the mean value recorded in group 4 (6.55±0.78) was significantly higher than all other groups (p=0.00).

Effect of thermocycling

In all groups and subgroups, the mean value of ΔE increased after thermocycling. The difference between values before and after thermocycling was not statistically significant in all subgroups of group1. In group 2, the difference was statistically significant only in subgroup B (p=0.038). In group 3 and group 4, the effect of thermocycling was statistically significant in subgroup "B" (p=0.011 and p=0.017 respectively) and in subgroup "Z" (p=0.008 and p=0.007 respectively).

All results are summarized and presented in table (2) and Figure (1).

TABLE (2) Descriptive statistics of ΔE, effect of thermocycling (Paired t test) and intergroups and intragroup comparisons (One way ANOVA test

	Thermo-cycling	Subgroup (B)		Subgroup (O)		Subgroup (Z)		P value between subgroups
		Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	
Group 1	Before	$5.7^{1aA,}$B	0.57	4.13^{bP}	0.81	3.58^{bQ}	0.68	0.000*
	After	6.24^{eL}	0.60	5.68^{eX}	1.31	4.14^{fY}	0.66	0.003*
	P#	0.115 ns		0.051 ns		0.278 ns		
Group 2	Before	4.63^{B}	1.00	3.43^{P}	1.03	$3.97^{P,Q}$	1.10	0.171 ns
	After	5.96^{aL}	0.66	4.09^{bY}	1.03	4.54^{bY}	1.14	0.011*
	P#	0.038*		0.273 ns		0.343 ns		
Group 3	Before	$5.29^{xA,B}$	0.51	5.35^{xQ}	0.57	$4.07^{yP,Q}$	0.52	0.001*
	After	6.22^{aL}	0.58	5.97^{aX}	0.67	5.08^{bY}	0.54	.012*
	P#	0.011*		0.243 ns		0.008*		
Group 4	Before	6.00^{mA}	0.68	6.14^{mQ}	0.68	4.96^{nP}	0.55	0.011*
	After	7.59^{aK}	0.81	6.46^{bX}	0.80	6.55^{bX}	0.78	0.049*
	P#	0.017*		0.569 ns		0.007*		
P value between groups	Before	0.019*		0.000*		0.030*		
	After	0.002*		0.003*		0.000*		

Significance level p≤0.05, *significant, ns=non-significant

P#: p value of significance of the paired difference (before/after thermocycling)

Post hoc test: Within the same group, materials (subgroups) in the same row sharing the same small superscript letter are not significantly different

Post hoc test: Within the same subgroup and within the same observation time (before/after), groups in the same column sharing the same capital superscript letter are not significantly different

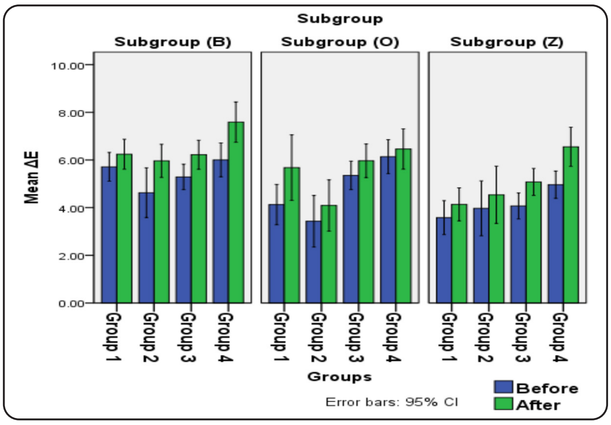

Fig. (1) Bar chart illustrating mean ΔE in different groups and subgroups before and after thermocycling

DISCUSSION

Developing tooth-colored restorations that mimic the optical qualities of the natural teeth is a main concern in restorative dentistry. The current trend toward simplification and shortening of clinical restorative treatment are two of the main reasons behind the development of universal (single shade) resin composites that can match a wide variety of classical shades [(42,43)]. The "blending effect" term was used to describe the color interaction between restorative materials and tooth tissues [(18)]. This effect works for the clinician by minimizing or neutralizing color mismatches. Color adjustment potential describes both physical and perceptual aspects of blending [44]. The blending effect seems to be a complex, multifactorial phenomenon. Many studies have examined the color adjustment potential of single-shade resin composite with chameleon characteristics (OMNICHROMA); however, to the best of our knowledge, no research has been conducted to assess the effect of in vitro accelerated ageing by thermocycling on this material when used in conjunction with a blocker (OMNICHROMA BLOCKER) for restorations of cavities with different dimensions.

The in vitro study design was chosen to assess the correlation between variations in cavity dimensions and color matching, which is not applicable in the clinical studies where both cavity size and depth are determined by the extent of carious lesions. Extracted teeth are multilayered and polychromatic; therefore, they were used in this study rather than using resin composite discs or teeth-like resin composite models [22]. The A2 shade was chosen because it is the most widely used shade in clinical practice [45]. The dentin influences tooth color more than the enamel; however, the latter influences color perception in terms of lightness. Class V cavities were prepared to overcome this problem because enamel thickness in the cervical area of the tooth is minimal, allowing the restoration shade to be mainly affected by dentin [36,46].

For instrumental measurement of color differences in this study, the CIELAB system was employed. The International Commission on Illumination recommends the use of the CIELAB system for evaluation of color differences due to its greater simplicity and easier calculations over other systems [47]. VITA Easyshade® V which is a portable, small, cordless, contact spectrophotometer was used in this study due to its high simplicity, precision and reliability with a reported accuracy and repeatability of over than 90% according to previous studies[48–51].

The comparison of commercial resin composites with different formulations is commonly employed for evaluating the effects of these compositional differences on their properties [52,53]. Filtek™ Z350 XT Universal Restorative is a commonly investigated restorative material in terms of the color matching and stability; therefore, it was chosen for the control group[17,20,52–54].

The results from the present study evidenced significant differences in color adjustment of single-shade resin composite (OMNICHROMA) with and without blocker (OMNICHROMA BLOCKER) in comparison with multi-shade resin composite (Filtek™ Z350 XT Universal Restorative). Thus, the first null hypothesis was rejected. Resin composite restorative materials contain three main components: an organic resin matrix, inorganic fillers, and an interphase. Each component can affect the optical properties of the restorations[18]. The significantly better color adjustment of Filtek™ Z350 XT Universal Restorative could be related to the resin matrix composition. The presence of higher molecular weight monomers as Bis-GMA increases the polymer crosslinking density, in addition to Bis-EMA which is characterized by lower water sorption attributed to the high degree of conversion and hydrophobicity[20]. The degree of conversion of the resin composite can affect the color adjustment. Resin composites with high conversion degrees have good color properties[18]. The hydrophobic nature of Filtek™ Z350 XT Universal Restorative resin reduces water sorption, solubility, and diffusion coefficient [55].

Another possible explanation of these results is the fact that Filtek™ Z350 XT Universal Restorative contains nano cluster–shaped fillers which have different color properties compared with the spherical nano-fillers found in OMNICHROMA BLOCKER and OMNICHROMA which have a filler content of 71% and 68% respectively [18]. It was reported that increasing the filler content adversely affects the color adjustment potential of resin composites [56].

This could explain the differences recorded between groups restored with OMNICHROMA and those restored with OMNICHROMA BLOCKER and OMNICHROMA. These results coincide with the results of El-Rashidy et al [20] who concluded that the color changes in the multi-shade (Filtek™ Z350 XT Universal Restorative) were significantly lower than the single-shade OMNICHROMA. In contrast to this, Al-Saudi et al [54] reported superior performance of OMNICHROMA in color stability compared with Filtek™ Z350 XT Universal Restorative. The differences in methodology could justify these contradictory findings. Al-Saudi et al (54) prepared disc-shaped resin composite specimens that were artificially aged in an accelerated ageing tester, while in our study, class V cavities were prepared and restored. The restorations were artificially aged by thermocycling.

The largest ΔE values were recorded in Group 4, with the largest restoration size and depth. Comparing the color adjustment among the different restoration sizes and depths within the same restorative material, it was shown that color adjustment increased when the size and depth of the cavity decreased, thus the second null hypothesis was rejected. Color adjustment of the restorative material is attributed to the high translucency of the material combined with the color reflection from the surrounding walls of the remaining tooth structure [12,55]. Increasing the size of the restoration, obscure the reflection of tooth shade through the restoration. A similar conclusion was affirmed by Paravina et al [26] and Abdelraouf and Habib [22]. They, too, confirmed an inverse relation between color adjustment and restoration size.

Regarding the effect of cavity depth, the findings of this study revealed no statistically significant differences in color adjustment between Group 1 (1.5 mm cavity depth) and Groups 2 and 3 (2 mm cavity depth), except for with Filtek™ Z350 XT. One possible explanation for this finding might be the relatively slight differences in cavity depths prepared in this study because the selection of these depths was restricted by the dimensions of the premolar teeth at the cervical third, where class V cavities were prepared [36].

Thermocycling is a commonly used ageing method to simulate the oral environment in which restorations are subjected to repeated cycles of thermal fluctuations caused by drinking and eating (57,58). The restorations were subjected to 10,000 thermal cycles, which are estimated to arbitrarily simulate one year of clinical service [59]. The mean ΔE values in all groups and subgroups increased after thermocycling, therefore, the third null hypothesis was rejected. Two factors may explain the reported increase in ΔE after thermocycling. When resin composite restorations are subjected to continuous thermal changes, internal stresses are induced as a consequence of the differences in coefficient of thermal expansion between the organic resin matrix and inorganic filler particles [60]. In addition, water sorption in resin composites is increased by thermal cycling [20,61]. These findings are in line with El-Refai [62] who reported that subjecting OMNICHROMA to 10,000 thermal cycles can adversely affect the color adjustment.

It should be noted that this study has some limitations. The color adjustment of restorations placed in extracted teeth differs from that of restorations placed in vital teeth because of structural changes in non-vital teeth. The variations in prepared cavities sizes and depths between the four groups were minimal due to the restrictions of the anatomy of the premolar teeth at the cervical third. Color adjustment of only one shade of resin composite was assessed. The color adjustment durability of restorations in the oral cavity can be influenced by several factors, such as masticatory forces, tooth brushing, saliva components, biofilm adhesion, and thermal fluctuations. In the present study, only thermal changes were simulated by thermocycling process that was performed in water without using any pigments. Different results might be obtained if any staining solution is used.

CONCLUSIONS

Based on the findings of this study, it can be concluded that:

1) The color adjustment of multi-shade resin composite was superior to single-shade resin composite, whether used alone or with blocker.
2) The color adjustment of the restorations depends on the prepared cavity dimensions. The color adjustment is inversely proportional to the cavity size and depth.
3) The color adjustment of restorations is adversely affected by thermocycling.

Being an in vitro study, simulating all complex interacting variables in the oral cavity was not achievable in this study. Therefore, it is recommended to conduct further clinical trials and long-term in vitro studies simulating other factors and evaluating the effect of different restoration shades in different classes of prepared cavities.

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REFERENCES

1. Akarslan Z, Sadik B, Erten H, Karabulut E. Dental esthetic satisfaction, received and desired dental treatments for improvement of esthetics. Indian J Dent Res [Internet]. 2009 Apr 1 [cited 2023 Jul 20];20(2):195–200. Available from: https://pubmed.ncbi.nlm.nih.gov/19553722/
2. Ismail EH. Color interaction between resin composite layers: An overview. Vol. 33, Journal of Esthetic and Restorative Dentistry. John Wiley and Sons Inc; 2021. p. 1105–17.
3. Samorodnitzky-Naveh GR, Geiger SB, Levin L. Patients' satisfaction with dental esthetics. J Am Dent Assoc [Internet]. 2007 [cited 2023 Jul 20];138(6):805–8. Available from: https://pubmed.ncbi.nlm.nih.gov/17545270/
4. Hasanain FA. Flexural Strength and Depth of Cure of Single Shade Dental Composites. J Pharm Res Int. 2021 Nov 11;33(49A):110–8.
5. Hynková K, Sarao SK, Voborná I, Levin L. Effect of assessor's sex on visual color matching in dentistry: A systematic review of the literature. Vol. 34, Journal of Esthetic and Restorative Dentistry. John Wiley and Sons Inc; 2022. p. 383–96.
6. Baldissera RA, Corrêa MB, Schuch HS, Collares K, Nascimento GG, Jardim PS, et al. Are there universal restorative composites for anterior and posterior teeth? J Dent. 2013 Nov;41(11):1027–35.
7. Lempel E, Lovász BV, Bihari E, Krajczár K, Jeges S, Tóth Á, et al. Long-term clinical evaluation of direct resin composite restorations in vital vs. endodontically treated posterior teeth — Retrospective study up to 13 years. Dent Mater. 2019 Sep 1;35(9):1308–18.
8. Aminoroaya A, Neisiany RE, Khorasani SN, Panahi P, Das O, Madry H, et al. A review of dental composites: Challenges, chemistry aspects, filler influences, and future insights. Vol. 216, Composites Part B: Engineering. Elsevier Ltd; 2021. p. 108852.
9. Paolone G, Orsini G, Manauta J, Devoto W, Putignano A. Vol. 9, The international journal of esthetic dentistry. 2014 [cited 2023 Jul 20]. p. 164–82 Composite shade guides and color matching. Available from: https://pubmed.ncbi.nlm.nih.gov/24765625/
10. Tsubone M, Nakajima M, Hosaka K, Foxton RM, Tagami J. Color shifting at the border of resin composite restorations in human tooth cavity. Dent Mater. 2012 Aug;28(8):811–7.
11. Yamaguchi S, Karaer O, Lee C, Sakai T, Imazato S. Color matching ability of resin composites incorporating supra-nano spherical filler producing structural color. Dent Mater. 2021 May 1;37(5):e269–75.
12. Iyer RS, Babani VR, Yaman P, Dennison J. Color match using instrumental and visual methods for single, group, and multi-shade composite resins. J Esthet Restor Dent. 2021 Mar 1;33(2):394–400.
13. Trifkovic B, Powers JM, Paravina RD. Color adjustment potential of resin composites. Clin Oral Investig. 2018 Apr 1;22(3):1601–7.
14. de Abreu JLB, Sampaio CS, Benalcázar Jalkh EB, Hirata R. Analysis of the color matching of universal resin composites in anterior restorations. J Esthet Restor Dent. 2021 Mar 1;33(2):269–76.

15. Chu SJ, Trushkowsky RD, Paravina RD. Dental color matching instruments and systems. Review of clinical and research aspects. In: Journal of Dentistry. 2010. p. e2–16.

16. Paravina RD, Westland S, Johnston WM, Powers JM. Color adjustment potential of resin composites. J Dent Res [Internet]. 2008 May 1 [cited 2023 Jul 20];87(5):499–503. Available from: https://journals.sagepub.com/doi/abs/10.1177/154405910808700515?journalCode=jdrb

17. Kim D, Park SH. Color and translucency of resin-based composites: Comparison of a-shade specimens within various product lines. Oper Dent [Internet]. 2018 Nov 1 [cited 2023 Jul 20];43(6):642–55. Available from: https://pubmed.ncbi.nlm.nih.gov/29630487/

18. Akgül S, Gündoğdu C. Color Change Evaluation of Three Universal Resin Composites after Storage in Water: An In Vitro Study. J Adv Oral Res. 2022 Aug 4;13(2):176–82.

19. Ismail EH, Dawson D V., Maia RR. A novel sample design for determining color compatibility between layered resin composite and vita shade guides. J Esthet Restor Dent. 2020 Jan 1;32(1):34–42.

20. El-Rashidy AA, Abdelraouf RM, Habib NA. Effect of two artificial aging protocols on color and gloss of single-shade versus multi-shade resin composites. BMC Oral Health. 2022 Aug 1;22(1):321.

21. Lee YK, Yu B, Zhao GF, Lim JI. Color assimilation of resin composites with adjacent color according to the distance. J Esthet Restor Dent. 2015 Mar 1;27(S1):S24–32.

22. Abdelraouf RM, Habib NA. Color-Matching and Blending-Effect of Universal Shade Bulk-Fill-Resin-Composite in Resin-Composite-Models and Natural Teeth. Biomed Res Int. 2016;2016:4183432.

23. Ruschel VC, Martins M V., Bernardon JK, Maia HP. Color match between composite resin and tooth remnant in class IV restorations: A case series. Oper Dent. 2018 Sep 1;43(5):460–6.

24. Vattanaseangsiri T, Khawpongampai A, Sittipholvanichkul P, Jittapiromsak N, Posritong S, Wayakanon K. Influence of restorative material translucency on the chameleon effect. Sci Rep. 2022 Dec 1;12(1).

25. Paravina RD, Westland S, Imai FH, Kimura M, Powers JM. Evaluation of blending effect of composites related to restoration size. Dent Mater. 2006 Apr;22(4):299–307.

26. Paravina RD, Westland S, Kimura M, Powers JM, Imai FH. Color interaction of dental materials: Blending effect of layered composites. Dent Mater. 2006 Oct;22(10):903–8.

27. Durand LB, Ruiz-López J, Perez BG, Ionescu AM, Carrillo-Pérez F, Ghinea R, et al. Color, lightness, chroma, hue, and translucency adjustment potential of resin composites using CIEDE2000 color difference formula. J Esthet Restor Dent. 2021 Sep 1;33(6):836–43.

28. Ismail EH, Paravina RD. Color adjustment potential of resin composites: Optical illusion or physical reality, a comprehensive overview. Vol. 34, Journal of Esthetic and Restorative Dentistry. John Wiley and Sons Inc; 2022. p. 42–54.

29. Lucena C, Ruiz-López J, Pulgar R, Della Bona A, Pérez MM. Optical behavior of one-shaded resin-based composites. Dent Mater. 2021 May 1;37(5):840–8.

30. Chen F, Toida Y, Islam R, Alam A, Chowdhury AFMA, Yamauti M, et al. Evaluation of shade matching of a novel supra-nano filled esthetic resin composite employing structural color using simplified simulated clinical cavities. J Esthet Restor Dent. 2021 Sep 1;33(6):874–83.

31. Śmielecka M, Dorocka-Bobkowska B. Comparison of two optical devices used for artificial tooth color selection. Dent Med Probl. 2022 Apr 1;59(2):249–53.

32. Chen H, Qu X. A systematic review of visual and instrumental measurements for tooth shade matching ostoeclast View project Progressive Oral Rehabilitation and Its Role in Cognition with Quality of Life Considerations View project [Internet]. 2012. Available from: https://www.researchgate.net/publication/232008810

33. Ferreira L de AQ, Peixoto RTR da C, Magalhães CS de, Sá TM, Yamauti M, Jardilino FDM. Comparison of instrumental methods for color change assessment of Giomer resins. Restor Dent Endod. 2022;47(1):e8.

34. Lee YK, Powers JM. Comparison of CIE Lab, CIEDE 2000, and DIN 99 color differences between various shades of resin composites. Int J Prosthodont [Internet]. 2005 [cited 2023 Jul 20];18(2):150–5. Available from: https://pubmed.ncbi.nlm.nih.gov/15889664/

35. Ahmed MA, Jouhar R, Vohra F. Effect of Different pH Beverages on the Color Stability of Smart Monochromatic Composite. Appl Sci. 2022 May 1;12(9).

36. Sanad M, Fahmy O, Abo Elezz A. Evaluation of Color Matching Ability of a Single Shaded Resin Composite Versus a Single Translucency Resin Composite With Different Teeth Shades. Dent Sci Updat. 2022 Sep 1;3(2):165–72.

37. Habib M, Fahmy O, Abo Elezz A. Evaluation of Shade Matching Ability of Three Resin Composites with Three

Different Teeth Shades (An In-Vivo Study). Dent Sci Updat. 2022 Sep 1;3(2):237–45.

38. Zulekha, Vinay C, Uloopi K, Rojaramya K, Penmatsa C, Ramesh M V. Clinical performance of one shade universal composite resin and nanohybrid composite resin as full coronal esthetic restorations in primary maxillary incisors: A randomized controlled trial. J Indian Soc Pedod Prev Dent. 2022 Apr 1;40(2):159–64.

39. Maiorov EE, Shalamai LI, Mendosa EY, Lampusova VB, Oksas NS. Spectral Methods and Means of Studying the Optical Properties of Dental Materials Based on Methyl Methacrylate Resins. Biomed Eng (NY). 2022 Mar 1;55(6):406–10.

40. Kim BJ, Lee YK. Influence of the shade designation on the color difference between the same shade-designated resin composites by the brand. Dent Mater. 2009 Sep;25(9):1148–54.

41. Korać S, Ajanović M, Džanković A, Konjhodžić A, Hasić-Branković L, Gavranović-Glamoč A, et al. Color Stability of Dental Composites after Immersion in Beverages and Performed Whitening Procedures. Acta Stomatol Croat. 2022 Mar 1;56(1):22–32.

42. Abdelhamed B, Metwally AAH, Shalaby HA. Rational durability of optical properties of chameleon effect of Omnichroma and Essentia composite thermocycled in black dark drinks (in vitro study). Bull Natl Res Cent. 2022 Dec;46(1):184.

43. Islam MS, Huda N, Mahendran S, Smriti Aryal AC, Nassar M, Rahman MM. The Blending Effect of Single-Shade Composite with Different Shades of Conventional Resin Composites-An In Vitro Study. Eur J Dent. 2022; 17(2):342–8.

44. Pereira Sanchez N, Powers JM, Paravina RD. Instrumental and visual evaluation of the color adjustment potential of resin composites. J Esthet Restor Dent. 2019 Sep 1;31(5):465–70.

45. Rodrigues S, Shetty SR, Prithviraj DR. An evaluation of shade differences between natural anterior teeth in different age groups and gender using commercially available shade guides. J Indian Prosthodont Soc [Internet]. 2012 Dec [cited 2023 Jul 21];12(4):222–30. Available from: https://pubmed.ncbi.nlm.nih.gov/24293919/

46. Morsy A, Gamal W, Riad M. Color Matching of a Single Shade Structurally Colored Universal Resin Composite with the Surrounding Hard Dental Tissues. Egypt Dent J. 2020 Oct 1;66(4):2721–7.

47. Lee YK, Yu B, Lee SH, Cho MS, Lee CY, Lim HN. Shade compatibility of esthetic restorative materials - A review. Vol. 26, Dental Materials. Elsevier Inc.; 2010. p. 1119–26.

48. Llena C, Lozano E, Amengual J, Forner L. Reliability of two color selection devices in matching and measuring tooth color. J Contemp Dent Pract. 2011;12(1):19–23.

49. Sarafianou A, Kamposiora P, Papavasiliou G, Goula H. Matching repeatability and interdevice agreement of 2 intraoral spectrophotometers. J Prosthet Dent [Internet]. 2012 Mar [cited 2023 Jul 20];107(3):178–85. Available from: https://pubmed.ncbi.nlm.nih.gov/22385694/

50. Igiel C, Lehmann KM, Ghinea R, Weyhrauch M, Hangx Y, Scheller H, et al. Reliability of visual and instrumental color matching. J Esthet Restor Dent. 2017 Sep 1;29(5): 303–8.

51. Klotz AL, Habibi Y, Corcodel N, Rammelsberg P, Hassel AJ, Zenthöfer A. Laboratory and clinical reliability of two spectrophotometers. J Esthet Restor Dent. 2022 Mar 1;34(2):369–73.

52. Schroeder T, da Silva PB, Basso GR, Franco MC, Maske TT, Cenci MS. Factors affecting the color stability and staining of esthetic restorations. Odontology [Internet]. 2019 Oct 1 [cited 2023 Jul 20];107(4):507–12. Available from: https://pubmed.ncbi.nlm.nih.gov/30924033/

53. Bahbishi N, Mzain W, Badeeb B, Nassar HM. Color stability and micro-hardness of bulk-fill composite materials after exposure to common beverages. Materials (Basel) [Internet]. 2020 Feb 1 [cited 2023 Jul 20];13(3):787. Available from: https://pubmed.ncbi.nlm.nih.gov/32050415/

54. Al-Saudi K, Badran O, Mohamed S, Nabil Amin A. Artificial Accelerated Aging Effects on the Color and Gloss Stability of Modern Universal Resin Composites: an in-Vitro Study. Egypt Dent J. 2022 Jul 1;68(3):2875–86.

55. Alhamdan EM, Bashiri A, Alnashmi F, Al-Saleh S, Al-Shahrani K, Al-Shahrani S, et al. Evaluation of smart chromatic technology for a single-shade dental polymer resin: An in vitro study. Appl Sci. 2021 Nov 1;11(21):10108.

56. Suh YR, Ahn JS, Ju SW, Kim KM. Influences of filler content and size on the color adjustment potential of nonlayered resin composites. Dent Mater J. 2017;36(1):35–40.

57. Amaral FLB, Colucci V, Palma-Dibb RG, Corona SAM. Assessment of in vitro methods used to promote adhesive interface degradation: A critical review. J Esthet Restor Dent. 2007;19(6):340–53.

58. Yantcheva SM. Marginal adaptation and micropermeability of class ii cavities restored with three different types of resin composites—a comparative ten-month in vitro study. Polymers (Basel). 2021;13(10):1660.

59. Teixeira GS, Pereira GKR, Susin AH. Aging Methods-An Evaluation of Their Influence on Bond Strength. Eur J Dent. 2021;15(3):448–53.

60. Porojan L, Toma FR, Uțu ID, Vasiliu RD. Optical Behavior and Surface Analysis of Dental Resin Matrix Ceramics Related to Thermocycling and Finishing. Appl Sci [Internet]. 2022 May 1 [cited 2023 Jul 21];12(9):4346. Available from: https://www.researchgate.net/publication/360203851_Optical_Behavior_and_Surface_Analysis_of_Dental_Resin_Matrix_Ceramics_Related_to_Thermocycling_and_Finishing

61. Reddy A, Kumar D, Shivanna V. Thermal cyclic changes on water sorption and solubility of composite restoratives - An in-vitro study. J Conserv Dent [Internet]. 2006 [cited 2023 Jul 21];9(2):63. Available from: https://www.researchgate.net/publication/239743339_Thermal_cyclic_changes_on_water_sorption_and_solubility_of_composite_restoratives_-_An_in-vitro_study

62. El- Refai D. Can Omnichroma revoke other restorative composites? Mechanical and physical assessment of Omnichroma dental resin restorative composite: An In- vitro study. Egypt Dent J [Internet]. 2022 Oct 1 [cited 2023 Jul 21];68(4):3701–16. Available from: https://edj.journals.ekb.eg/article_267098.html