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
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 outcome (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 l’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 (ZrO₂) and silicon dioxide (SiO₂) 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 chairside 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).
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 \((\alpha)\) level of 5%, \((\beta)\) 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 mm³)
**Group 2 (G2):** mesio-distally = 3 mm, occluso-gingivally = 1.5 mm, and depth = 2 mm. (Volume = 9 mm³)

**Group 3 (G3):** mesio-distally = 3 mm, occluso-gingivally = 2 mm, and depth = 2 mm. (Volume = 12 mm³)

**Group 4 (G4):** mesio-distally = 3 mm, occluso-gingivally = 2 mm, and depth = 2.5 mm. (Volume = 15 mm³)

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/cm² 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) Al₂O₃ 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:

\[
\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}
\]

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 ∆E 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).
EFFECT OF CA VITY DIMENSIONS ON COLOR ADJUSTMENT OF SINGLE-SHADE VERSUS

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

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

<table>
<thead>
<tr>
<th>Thermocycling</th>
<th>Subgroup (B)</th>
<th>Subgroup (O)</th>
<th>Subgroup (Z)</th>
<th>P value between subgroups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev</td>
<td>Mean</td>
<td>Std. Dev</td>
</tr>
<tr>
<td>Group 1</td>
<td>Before</td>
<td>5.7$^{+A}$</td>
<td>0.57</td>
<td>4.1$^{+P}$</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>6.24$^{+L}$</td>
<td>0.60</td>
<td>5.68$^{+X}$</td>
</tr>
<tr>
<td>P#</td>
<td>0.115 ns</td>
<td></td>
<td>0.051 ns</td>
<td></td>
</tr>
<tr>
<td>Group 2</td>
<td>Before</td>
<td>4.63$^{+B}$</td>
<td>1.00</td>
<td>3.43$^{+K}$</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>5.96$^{+L}$</td>
<td>0.66</td>
<td>4.09$^{+V}$</td>
</tr>
<tr>
<td>P#</td>
<td>0.038*</td>
<td></td>
<td>0.273 ns</td>
<td></td>
</tr>
<tr>
<td>Group 3</td>
<td>Before</td>
<td>5.29$^{+A,B}$</td>
<td>0.51</td>
<td>5.35$^{+Q}$</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>6.22$^{+L}$</td>
<td>0.58</td>
<td>5.97$^{+X}$</td>
</tr>
<tr>
<td>P#</td>
<td>0.011*</td>
<td></td>
<td>0.243 ns</td>
<td></td>
</tr>
<tr>
<td>Group 4</td>
<td>Before</td>
<td>6.00$^{+A}$</td>
<td>0.68</td>
<td>6.14$^{+Q}$</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>7.59$^{+K}$</td>
<td>0.81</td>
<td>6.46$^{+X}$</td>
</tr>
<tr>
<td>P value between groups</td>
<td>Before</td>
<td>0.017*</td>
<td></td>
<td>0.569 ns</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>0.002*</td>
<td></td>
<td>0.003*</td>
</tr>
</tbody>
</table>

Significance level $p \leq 0.05$, *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 $\Delta E$ in different groups and subgroups before and after thermocycling
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 Easycolor® 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 ∆E 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 ∆E values in all groups and subgroups increased after thermocycling, therefore, the third null hypothesis was rejected. Two factors may explain the reported increase in ∆E 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 (20,64). 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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