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EFFECT OF RESTORATION DEPTH AND THERMOCYCLING ON COLOR MATCHING OF A SMART SINGLE SHADE UNIVERSAL RESIN COMPOSITE WITH THE SURROUNDING HARD DENTAL TISSUES

Sayed Mohamed Ghorab*, Rabab Mehesen** ,
Mohamed Samir Elnawawy** *and* Hagag Abdel-Kader Atya*

ABSTRACT

Objective: To determine the shade matching ability of a single-shade universal composite with the surrounding hard dental tissues at different cavity depths and after thermocycling.

Materials and Methods: Ninety extracted premolars were selected and Class V cavities were then prepared and teeth were divided in to 3 groups according to cavity depths; Group 1: 1 mm cavity depth, Group 2: 2 mm cavity depth and Group 3: 3 mm cavity depth. Specimens were restored with an Omnichroma shade matching composite and stored in distilled water at 37° C for 24 h. Subsequently, each group was subdivided in to 3 subgroups according to thermocycling protocols as follow; subgroup A not thermocycled (as control), subgroup B aged by 5000 TC and subgroup C aged by 10000 TC. Shade evaluations were recorded using the digital spectrophotometer. The color data were statistically analyzed, and was considered statistically significant at $P = 0.05$.

Results: There was no significant difference in the L*a*b* values between the restoration and tooth for all groups and subgroups ($P > 0.05$). Color differences (ΔE) were significantly higher at restorations with 1 mm cavity depth than that with 2 mm and 3 mm cavity depths ($P < 0.05$). On contrary, thermocycling led to significant color changes ($P < 0.05$), compared to control group.

Conclusion: Omnichroma single-shade universal composite is good alternative for color-matched, esthetically satisfying restorations. Restoration depth was positively associated with shade matching ability, while thermocycling negatively affected it.

KEYWORDS: Omnichroma, cavity depth, thermocycling, shade matching ability

* Department of Dental Biomaterials, Faculty of Dentistry, Mansoura University, Mansoura, Egypt
** Department of Conservative Dentistry, Faculty of Dentistry, Mansoura University, Mansoura, Egypt

INTRODUCTION

For aesthetic restoration of anterior or posterior teeth, direct resin composite material is firstly chosen.[1] The optical qualities of resin composite; including its translucency, opalescence, and diffusion light transmission characteristics, and the texture of the restoration surface; may have an impact on how will be the tooth/resin composite color blending.[2] Also, the cavity depth, boundaries extensions and location might have an effective role in this color match.[3,4]

The issue of matching the resin composite's color to the surrounding tooth has not been mostly resolved.[5] This is due to the restricted color variations of currently available commercial resin composites (RCs), as well as the fact that tooth natural color is influenced by the kind, thickness of tooth tissues such as enamel and dentin, the restoration's location within the oral cavity or directly on the tooth surface, and tooth age.[6] Enamel exhibits a higher degree of light transmission due to its highly mineralized prismatic structure, low organic content, and minimal amount of water.[7] Other factors that affect how people perceive tooth color include illumination, translucency, opacity, light scattering, gloss, and human eye sensitivity.[8]

Chameleon effect is a phenomenon claimed by the dental manufacturers and professionals that the clinically perceived color difference between tooth and resin composite restoration is less than the expected by viewing them individually.[9] This phenomenon is thought to be caused by the color shift of resin composite restoration after color reflection by surrounding tooth structures.[10] By the virtue of discovering these mechanisms and materials that enable resin composite restorations to shift to natural color of the surrounding tooth giving significant improvement of resin composite restorations esthetics. It will simplify the step of shade matching, and reduce the number of hues used.[11] One of the materials had been developed and became trendy that is closely mimic the surrounding healthy tooth in color is the smart monochromatic shade OMNICHROMA resin composite that is manufactured in Japan by Tokuyama Dental America Inc. This resin composite presents in only one universal shade aiming to match any surrounding shades once it is placed and cured.[12] Unquestionably, its wide color-matching capability will eliminate shade-selection process and decreases composite inventory. Moreover, chair time and wastage of unused composite shades will be reduced.[13,14]

Although the satisfactory performance of this single shade composite resin in terms of chair time and blending effect, further in vitro investigations of this restorative material regarding restoration depths and aging by thermocycling protocols are required. Therefore, this study aimed to evaluate the color-matching ability of OMNICHROMA resin composite in different restoration depths and after different thermocycling protocols. The null hypotheses were that (1) restoration depth will not affect the color matching of single shade composite resin restorative material, and (2) thermocycling protocol will not affect the color matching of single shade composite resin restorative material.

MATERIALS AND METHODS

OMNICHROMA resin composite and its corresponding self-etch Palfique Bond were used in this study. The compositions, batch numbers and manufacturers are shown in detail in Table 1.

Teeth selection and grouping

Ninety extracted human maxillary premolars with different shades were collected for the study protocol. These teeth were extracted from patients will undergo orthodontic treatment and then stored in distilled water in an incubator (BTC, Biotech, Egypt) at 4° C. The teeth used in this study were obtained according to the protocol reviewed and approved by Ethical Committee, Faculty of Dentistry, Mansoura University, Mansoura, Egypt

TABLE (1) The materials used in this study

Material	Composition	Batch no	Manufacturer
OMNICHROMA light-cured, radiopaque) single shade universal (composite	**Inorganic filler (Filler loading 79% by wt and 68% by vol):** Supra-nano sized uniform spherical filler of SiO_2-ZrO_2 (260 nm $_2$) **Organic matrix**: UDMA, Triethylene glycol dimethacrylate , Mequinol, Dibutyl hydroxyl toluene, UV absorber	002E60	Tokuyama Dental Corp., Tokyo, Japan
Palfique Bond light-cured, self-etch) (adhesive	Phosphoric acid monomer, Bisphenol A di (2-hydroxypropoxy) dimethacrylate (Bis-GMA), Hydroxyethyl methacrylate, Triethylene glycol dimethacrylate, Camphorquinone, alcohol	163E62	Tokuyama Dental corp., Tokyo, Japan

(protocol # A0107023DM). Using an ultrasonic scaler, all teeth were cleansed from any calculus deposits or attached soft tissue debris, and then polished with a prophylaxis paste and polishing brush. They were microscopically examined under a magnification of 20X to ensure that there were no cracks, fractures, cavities to be excluded if present.

The specimens were divided randomly into 3 main groups according to planned cavity depth as follow respectively; Group (1) in which cavity depth was 1 mm, Group (2) in which cavity depth was 2 mm, and Group (3) in which cavity depth was 3 mm. Standard box-shaped cavity preparation with dimensions mesiodistal (3mm) and occlusocervical (4mm) at labial cervical third of teeth crown were prepared. This is done by cutting a window inside a metal matrix band with the same dimensions which fixed by Tofflemire universal retainer around the tooth.[15] A high-speed handpiece, a cylindrical diamond abrasive point (#D11, ISO 108 010, GC, Tokyo, Japan), an endodontic rubber stopper, and air and water spray were used to prepare the specimens while holding them by hand via the window. A single operator prepared the cavities, and the bur was changed for a new one every four cavities.[16] Each depth was measured with a periodontal probe after preparation to ensure that the depth was set. A 45-degree bevel was prepared to all the cavity margins.

Specimens' restoration and thermocycling

The bonding strategy used for OMNICHROMA RC was self-etch (SE). Two layers of Palfique bond were applied using a micro brush actively for 20 seconds (10 seconds for each layer), then air spread and dried for 5 seconds, and cured for 10 seconds using light curing unit (Elipar FreeLight 2, 3M ESPE; St Paul, MN, USA, light output: 1226 mW/cm^2). Using a Teflon coated plastic filling tool, Omnichroma restorative material was packed in to the prepared cavities in single layer for groups 1 and 2 and in double layers in group 3. To reduce the oxygen inhibition layer and to achieve the smoothest possible surface, the restoration was covered with celluloid strip, then light-cured for 40 seconds. All the resin composite restorations were finished and polished using multi-step system (Sof-Lex Pop-on discs, 3M, ESPE Dental Products, USA) with mild hand pressure and water cooling. After that, the specimens were stored again in distilled water for 24 h at 37° C in the incubator.

After that, the specimens of each group were subdivided randomly according to thermocycling protocol into 3 subgroups as follow; subgroup A as control (no thermocycling), subgroup B (5000 cycles), and subgroup C (10000 cycles) (n=10). The thermocycling was done in 5°C and 55°C, with a dwell time of 20 seconds and transfer time for 5 seconds using a thermocycling device (Thermocycler, Robota industries, Alexandria, Egypt).

Color measurement of restored teeth

A digital spectrophotometer (Vita Easyshade®V, Vita Zahnfabrik, Bad Sackingen, Germany) was used to measure the color. To avoid the possibility of absorption effects, the specimen was placed on a white background for color measurement. The L*a*b* and shade evaluations were recorded at a total of 5 locations (4 sites around the restoration which usually being 1 mm apart and the 5th site directly over the restoration). Then, the readings captured on those 4 sites were averaged and compared to the 5th one. The CIELAB color system was employed, comprising L*, a*, and b* axes identification; L ranged from 0 to 100 (brightness to darkness), a axis represented red to green colors (90 to 70 range value), and b axis represented yellow to blue colors (coordinate value range from: 80 to 100).The readings were measured according to the CIE L*a*b* color space relative to the CIE standard illuminant D65. The shades of all specimens were calculated in form of (ΔE) using Hunter's equation: $\Delta E = [\Delta L^2 + \Delta a^2 + \Delta b^2]$ ½ (as ΔL, Δa, and Δb are the differences between the recorded and predicted CIE LAB values of the shade).[17]

Statistical analysis

Data were tabulated, and analyzed using SPSS program (SPSS v22.0; SPSS Inc). Test of normality was performed using Shapiro Wilk test and homogeneity of variances by the Levene's test. The data were presented as mean ± standard deviation (SD) for descriptive statistics. The values of L*a*b* at the 4 sites around the restoration (E) were averaged and compared to the values of L*a*b* of the restoration (R) for each group and subgroup using independent t-test. Two-way ANOVA test was used to compare (ΔE) among different groups and subgroups, and followed by Tukey's multiple comparisons if significant differences were detected. P was significant at 5%.

RESULTS

Comparison of L*a*b* values between areas for all groups and subgroups

A comparison of values of L*a*b* between restoration (R) and enamel next to restoration margins (E) for all groups and subgroups is presented in Table 2. For all groups and subgroups, there was no significant difference in L*a*b* values between R and E.

Effect of restoration depth on color difference (ΔE)

A comparison of (ΔE) among different groups and subgroups is presented in Table 3 and Figure 1. There was a significant difference among groups for each subgroup identified by 2-way ANOVA test. For all subgroups, Group 1 recorded the highest (ΔE 2.37) then Group 2 (ΔE 1.69), and Group 3 recorded the lowest (ΔE1.29). Also, there was a significant difference between each 2 groups by Tukey test.

Effect of thermocycling on color difference (ΔE)

A comparison of (ΔE) among subgroups in different groups is presented in Table 3 and Figure 2. There was a significant difference among subgroups in each group by 2-way ANOVA test, $p=0.03$, $p=0.023$, and $p=0.017$ for groups 1, 2, and 3 respectively). For all subgroups; subgroup C recorded the highest (ΔE) followed by subgroup B, and subgroup A recorded the lowest (ΔE). For groups 1 and 2; there was a significant difference between each 2 subgroups by Tukey except between subgroup A and subgroup B. For group 3; there was a significant difference between each 2 subgroups by Tukey, except between subgroup B and subgroup C.

TABLE (2): Comparing L*a*b* values between restoration (R) and surrounding enamel (E) for all groups and subgroups

	Group 1 (1 mm restoration depth)			**Group2 (2 mm restoration depth)**			**Group3 (3 mm restoration depth)**		
	Subgroup A (control)	Subgroup B (5000 TC)	SubgroupC (10000 TC)	SubgroupA (control)	Subgroup B (5000 TC)	Subgroup C (10000 TC)	Subgroup A (control)	Subgroup B (5000 TC)	SubgroupC (10000 TC)
	X ± SD	X ± SD	X ± SD	X ± SD	X ± SD	X ± SD	X ± SD	X ± SD	X ± SD
L^*_R	71.41 ± 0.75	71.87 ± 0.83	71.96 ± 1.25	69.88 ± 1.47	74.60 ± 1.17	73.53 ± 1.39	73.06 ± 1.07	71.48 ± 1.12	70.20 ± 0.75
L^*_E	70.18 ± 0.12	70.63 ± 1.32	70.27 ± 1.58	68.49 ± 1.01	73.41 ± 1.27	72.19 ± 1.41	72.38 ± 1.20	70.52 ± 1.16	69.10 ± 0.76
P	0.148	0.377	0.359	0.394	0.431	0.437	0.609	0.491	0.283
a^*_R	0.42 ± 0.15	0.66 ± 0.24	0.88 ± 0.05	0.23 ± 0.15	0.71 ± 0.35	0.80 ± 0.60	0.33 ± 0.27	0.71 ± 0.38	0.28 ± 0.08
a^*_E	0.18 ± 0.10	0.25 ± 0.06	1.14 ± 0.71	0.22 ± 0.24	0.71 ± 0.01	0.50 ± 0.54	0.18 ± 0.01	0.72 ± 0.09	0.32 ± 0.37
P	0.204	0.143	0.650	0.982	0.986	0.646	0.513	0.987	0.895
b^*_R	6.05 ± 1.14	7.20 ± 1.16	5.79 ± 1.35	6.12 ± 0.71	6.28 ± 1.61	5.77 ± 1.40	4.98 ± 0.59	7.79 ± 1.48	4.31 ± 0.63
b^*_E	6.17 ± 0.52	7.47 ± 0.61	5.64 ± 0.20	5.95 ± 0.40	5.41 ± 1.54	4.79 ± 1.35	5.18 ± 0.28	7.07 ± 1.41	5.43 ± 0.11
P	0.901	0.789	0.894	0.802	0.637	0.548	0.709	0.654	0.133

X mean, SD standard deviation, *p is significant at 5% level.

TABLE (3): Comparison of ΔE between groups and subgroups

	Group 1		**Group2**		**Group3**		**2-way ANOVA p value**
	X	SD	X	SD	X	SD	
Subgroup A	$2.01^{A,a}$	0.01	$1.41^{B,a}$	0.08	$0.99^{C,a}$	0.16	<0.001*
Subgroup B	$2.01^{A,a}$	0.06	$1.50^{B,a}$	0.11	$1.21^{C,b}$	0.06	<0.001*
Subgroup c	$2.37^{A,b}$	0.04	$1.69^{B,b}$	0.06	$1.29^{C,b}$	0.10	<0.001*
2-way ANOVA p value	0.003*		0.023*		0.017*		

X mean, SD standard deviation. *p is significant at 5% level. Different uppercase letters in the same raw indicate significant difference among groups within each subgroup level, while same letters indicate no significant difference between groups. Different lowercase letters in the same column indicate significant difference among subgroups within each group level, while same letters indicate no significant difference among subgroups

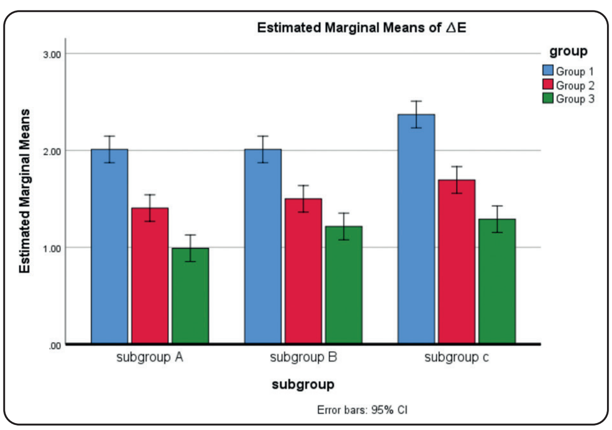

Fig. (1) Comparison of (ΔE) among groups for different subgroups.

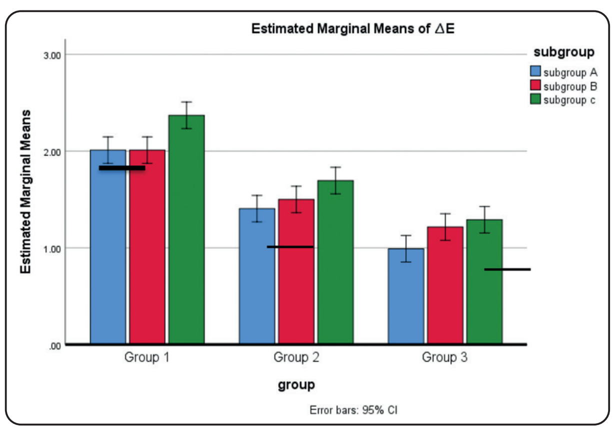

Fig. (2) Comparison of (ΔE) among subgroups for different groups. Line connecting bars indicate no significant difference between subgroups.

DISCUSSION

The need for restorations that looked as natural as possible led to the development of multi-shade resin composites, comprising enamel and dentin resin composite shades with different optical properties to harmonize with natural tooth.[18] The future of resin composites is moving toward an integrated technology as request for better aesthetics and functionality rises. Clinicians are dreaming of materials that are easier to use, could save time, and meet the high expectations of the patient.[4] Lately, single-shade resin composite was introduced to the dental market in an effort to speed up the shade selection process and shorten the application time compared to other multi-shade resin composites. Omnichroma, being one of the most clinically successful single-shade composites, was used in the present study. It is considered one of the most studied single-shade materials, with its optical characteristics and shade matching ability have been the subject of several researches.[8,19-23]

The manufacturer claims that Omnichroma does not include pigment but instead has the potential to match a wide spectrum of colors, including all Vita classical shades A1–D4 with a single shade. By the fact of utilizing uniform spherical supra nano-sized (260 nm) fillers of silicon dioxide and zirconium dioxide and distributed homogeneously, it achieves these spectacular color properties. Without the need of extra pigments, the monomer has the precise size and shape to produce a reddish-to-yellow color following polymerization. This is consistent with the earlier studies that reported a relation between the blending effect (BE) and translucency of the surrounding tooth tissues.[4,24] The color matching ability of Omnichroma at two different cavity depths was investigated. Moreover, its instrumental color adjustment potential was shown to improve after 1 month storage in distilled water.[25] Yet, the shade matching of this restorative material with the surrounding hard dental tissues in different cavity depths under different thermocycling protocols, according to our knowledge, are not widely investigated.

It was stated that the dentine beneath the enamel determines the shade of the natural teeth, with the latter has a minor impact on the color of the teeth but primarily affects how light the shade appears.[5] In the present study, to overcome this problem, Class V cavities were selected to be prepared in the tooth specimens because the slight enamel thickness in this region allowed the restoration shade to be influenced by the dentin color.[26] Additionally, to ensure excellent cutting efficiency, new rotary cutting tips were utilized every five cavities.[27]

Shade matching procedure can be determined chair-side via visual evaluations and/or instrumental measurements. Since the likelihood that ambient lightening conditions could alter how accurately a visual shade is established, instrumental measures are regarded to be more reliable than visual evaluations. To eliminate human errors in identifying shade discrepancies, Vita Easy Shade® V spectrophotometer device was used in the current study to record the shade scores of all restorations. This device has its particular light source for illuminating the tested specimen's surface, and the results are unaffected by ambient lighting which was confirmed by previous several researches.[28,29] Dozic et al. reported that VITA Easy Shade spectrophotometer provided dependable reliability and accuracy by comparison to another five available devices by either in vivo and in vitro studies.[30]

Although there are a number of color difference calculation formulas, the CIE Lab system is the one that is most frequently used in dental research. It defines the color using three spatial coordinates; L, a, and b and characterizes it using human perception. The ΔE value of 3.7 is an acceptable threshold, according to Khashayar et al., who conducted a dental literature search to gather information on acceptability and perceptibility thresholds. This value has served as a benchmark for various researchers.[17,31] As well as, the results of the present study showed that the mean values of the restorations exhibited close numbers to the mean values of the surrounding enamel at 4 different points by comparing L*a*b* mean values between the restoration and the surrounding enamel. These findings support the color matching adaptation of Omnichroma.

The color matching of restorative materials in clinical circumstances is influenced by a number of factors. In addition to material-specific factors like the type of photoinitiators and activators, monomers, filler types, and size, they include the restoration's size, depth, and distance from dental tissues. Regardless of restoration size, a thicker restoration allows the restorative materials to more accurately represent their color characteristics.[24,32] When the effect of restoration depth on color difference (ΔE) was compared in the present study, 1 mm restorations recorded the highest ΔE values followed by 2 mm restorations, and 3 mm restorations recorded the lowest ΔE values. These results indicate that color matching was higher for 3 mm restorations than for 2 mm and 1 mm restorations; thus, the first null hypothesis was rejected.

A substance starts to deteriorate the moment it is put in a patient's mouth. The examined material was aged in this study to better replicate the clinical setting in the lab. The literature has introduced a number of artificial aging procedures, such as immersion and thermocycling. One of the main goals of the present study was to assess the influence of thermocycling on color matching because dental restorations are often subjected to such thermal changes rather than constant temperature in clinical settings. The specimens were aged for 5,000 cycles and 10,000 cycles to represent roughly six months and one year of clinical function because it has been claimed that 10,000 cycles in a thermocycling apparatus represent one year of clinical performance.[33]

Also, the results of this study showed that thermocycling caused a significant increase in (ΔE). Subgroups C (10,000 cycles) had the highest (ΔE) followed by subgroup B (5,000 cycles), and subgroup A (control) recorded the lowest ΔE. Thus, the second null hypothesis was rejected. These results are most likely based on the fact that the filler particles and resin matrix have different thermal expansion coefficients resulting in the material experiencing internal stresses due to constant temperature fluctuations. Consequently, thermal cycling makes resin composites absorb more water.[34,35] Moreover, the Omnichroma matrix contains monomers (UDMA and TEGDMA) with lower molecular weights. Some investigations claim that TEGDMA (hydrophilic monomer) improved water sorption, making color matching more difficult.[36]

One of the limitations of this study was the investigation of only one brand of single shade composites. Single shade composites produced by various manufacturers have different formula and chemical compositions, giving these materials different physical and optical characteristics. So far, the findings of this study cannot be applied to other single shade composite brands. Another limitation is that thermocycling was employed to age the specimens to simulate the intraoral conditions; however, it does not accurately reproduce the whole intraoral environment or what the restorative materials are subjected to other than heat.

CONCLUSIONS

Despite the limitations of this in-vitro study and based on the results, the following conclusions can be made;

1. The average scores of the L*a*b* of omnichroma shade matching composite are very close to that of the enamel for class V restorations
2. Resin composite restorations with a depth of 1 mm produce better color blending than restorations with a depth of 2 mm and 3 mm for all subgroups.
3. In all groups, thermocycling aging had significant effect on color changes (ΔE), in contrast to control group.

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