Article

Effect of Different pH Beverages on the Color Stability of Smart Monochromatic Composite

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Abstract: Omnichroma is a smart monochromatic material and is believed to attain the shade of the surrounding tooth structure in which it is placed. However, the color stability of this material is unknown. Therefore, this study was conducted to evaluate the effect of different pH beverages on the color stability of the Omnichroma composite and its comparison with micro-hybrid composite resin. Sixty extracted human maxillary premolars of different shades, viz. A2, A3, B2 and B3, were selected in equal numbers. A Class V cavity was prepared on the buccal and palatal sides of each tooth. After the cavity preparation, etching of the cavity was performed with 35% phosphoric acid followed by bonding. The prepared cavities were then filled with Omnichroma composite resin on the buccal side and Filtek Z250 composite on the palatal side. The baseline color measurements of all tooth samples were performed by a spectrophotometer. The teeth were then divided into three groups, the Pepsi group, coffee group and milk tea group. Five teeth from each shade, viz. A2, A3, B2 and B3, were immersed in 10-mL of Pepsi, coffee, and milk tea for 14 days. After the completion of the 14 days, the teeth were rinsed and kept in distilled water for 24 h. Finally, a spectrophotometer was used to calculate the color alteration value $\Delta E$. Mean difference in $\Delta E$ values of the samples before and after immersion in different beverages was calculated and analysed by SPSS 25. One-way ANOVA test was applied to compare groups. Further stratification was performed using the Post-Hoc Tukeys test. Samples immersed in milk tea showed a statistically significant difference ($p < 0.05$) in A2, A3, and B2 shades of the OM-milk tea group in comparison with the FT-milk tea group. In summary, the immersion of teeth in beverages with a different pH and colorants showed an apparent alteration in the color of both the smart monochromatic and micro-hybrid composites. Hence, the type of resin composite material should be selected wisely depending on the patient’s drinking and social habits.

Keywords: color stability; dentistry; micro-hybrid composite; omnichroma; restorative; smart monochromatic material

1. Introduction

Composite resin is considered one of the best direct restorative materials because it mimics the aesthetics of natural tooth tissue [1–3]. It is widely used to restore the broken-down teeth that are either carious or fractured, the buildup of congenitally malformed teeth, veneering of discolored natural teeth and cementation of the orthodontic appliances on the teeth [4]. The clinical success of dental composites depends upon their physical, chemical, and mechanical properties, which are greatly influenced by the characteristics of the oral environment and properties of the resin materials [5,6].

One of the physical properties of composites that is of the utmost importance is the color stability of the material. The color stability of resin composites can greatly affect their clinical longevity and performance within the oral cavity [7] and is reported as one of the main reasons for replacing the restorations [8]. Manufacturers have focused on making this
material’s color stable over time. Various etiological factors are responsible for the color changes in resin composites. Extrinsic discoloration may occur due to oral hygiene habits, or the presence of certain chromogens in the diet, tobacco, water absorption, and surface roughness of the material [9,10], whereas intrinsic factors occur due to the physio-mechanical reaction within the resin material, depending upon the type of resin matrix, which ultimately affects the hydrophilic/hydrophobic nature of the material, filler weight, size and distribution, the type of photoinitiator used and the degree of polymerization [11,12].

The human oral cavity is exposed to a variety of dietary beverages throughout the day. The most commonly consumed beverages in our population are milk tea, coffee, and carbonated soft drinks. All of these have been shown to have a significant staining effect on the resin composites. Previous studies have indicated the deleterious effect of these beverages on conventional and bulk-fill composites [7,13–15].

Nowadays, the trend of using the smart monochromatic shade of composite is booming. Dentists are more inclined towards using smart chromatic technology owing to the fact that it reduces the need for a variety of composite shades in inventory, minimizes the wastage of unused composite shades, minimizes chairside time, eliminates the need for shade selection, and reduces reliance on shade-matching procedures [16]. Omnichroma (OM) is one of the smart chromatic materials and is believed to attain the shade of the surrounding tooth structure in which it is placed. However, knowledge regarding the color stability of this material is scarce in scientific literature [17,18]. Therefore, it is worthwhile to investigate the color stability of Omnichroma in comparison to micro-hybrid composite.

2. Materials and Methods

Sample size was calculated using online OpenEpi (www.OpenEpi.com) on 12 October 2021 and by keeping a confidence interval of 95%, power of test of 80%, and mean of 3.41 ± 0.37 (Group 1) and 4.09 ± 0.77 (Group 2) at 14 days [16], the sample size for each group was 13. For the convenience of even grouping and subgrouping, sixty extracted human maxillary premolars of different shades, viz. A2, A3, B2 and B3, were selected in equal numbers (15 each shade) after ethical approval (KFU-REC/2021-02-22). These teeth were grossly intact, either without any fractures, caries, or resorption. Each tooth was autoclaved in a solution of glycerin (Equate, Wal-Mart Stores Inc., Bentonville, AR, USA) and distilled water. A round diamond bur #04 (Mani, Tokyo, Japan) was used to prepare a Class V cavity on the buccal and palatal sides of each tooth. The dimensions of the Class V cavity were 2 mm in depth, 3 mm in height and 5 mm in length, as shown in Figure 1. After the cavity preparation, etching of the cavity was performed with 35% phosphoric acid (Ultradent, South Jordan, USA) followed by bonding with Prime & Bond NT (Dentsply Sirona, NC, USA) as per manufacturer’s instructions. The prepared cavities were then filled with Omnichroma composite resin (Tokuyama Dental Corporation, Tokyo, Japan) on the buccal side and Filtek Z250 composite (3M ESPE; St. Paul, MN, USA) on the palatal side.

The composition of both composites is listed in Table 1. LED curing light (LUX E, Guilin Woodpecker, Guilin, Guangxi, China) was used to cure each composite for 20 s. The final finishing of composite restorations was performed using white stone bur (Shofu, Kyoto, Japan) and Soflex disc (3M, Minnesota, USA).

Figure 1. The dimensions of Class V cavity, (a) depth, (b) height, (c) length.
Table 1. Composition of Filtek Z250 and Omnichroma Composites.

| Filtek Z250 Composite | Omnichroma Composite |
|-----------------------|----------------------|
| BIS-GMA (Bisphenol A diglycidyl ether dimethacrylate), UDMA (urethane dimethacrylate), and Bis-EMA (Bisphenol A polyethylene glycol diether dimethacrylate) | UDMA, TEGDMA |
| 60% (volume) silica/zirconia fillers | Uniform-sized supra-nano spherical filler (260 nm spherical SiO$_2$-ZrO$_2$) |
| The filler particle size distribution is from 0.01 µm to 3.5 µm with an average particle size of 0.6 µm | Composite filler (include 260 nm spherical SiO$_2$-ZrO$_2$). Filler loading 79 wt% (68 vol%) |

The baseline color measurements of all tooth samples were performed by a spectrophotometer (Vita Easyshade®V Compact Vita, Zahnfabrik, Bad Sackingen, Germany), as shown in Figures 2 and 3. Teeth were then divided into three groups according to the beverage solutions.

Pepsi Group ($n = 20$): Five teeth of each shade viz. A2, A3, B2 and B3 restored with Omnichroma(OM) on buccal side and Filtek Z250 (FT) on the palatal side were immersed in 10 mL of Pepsi soft drink (Pepsi-cola Company, Jeddah, Saudi Arabia) (pH 2.52). The Pepsi was replaced after every 24 h for 14 days [16].

Coffee Group ($n = 20$): Five teeth of each shade viz. A2, A3, B2 and B3 immersed in flasks containing 10 mL of coffee (Nescafe Classic, Nestle Suisse, Vevey, Switzerland) with a pH around 5.45 for 14 days and the coffee was replaced after every 24 h.

Milk Tea Group ($n = 20$): Similarly, five teeth from each shade viz. A2, A3, B2 and B3 were submerge in 10 mL of milk tea (Lipton, Unilever, Pakistan) (pH 6.5) for 14 days, which was replaced after every 24 h.

After the completion of 14 days, the teeth were rinsed and kept in distilled water for 24 h. A spectrophotometer (Vita Easyshade®V Compact Vita, Zahnfabrik, Bad Sackingen, Germany) was calibrated prior to the measurement of color alteration value, as directed by the manufacturer. Each tooth sample was dried with an absorbent point after removal from the distilled water. The teeth were stabilized in custom-made box. The tip of the...
spectrophotometer was placed at the center of each restoration and three measurements were taken. All procedures were performed by the principal investigator. At last, the mean difference in the color alteration (ΔE) values of the teeth samples before and after immersion in different beverages was calculated and analyzed using SPSS (Version 25.0. Armonk, NY, USA). A one-way ANOVA test was applied for comparison among groups. The distribution of data was analyzed for normality testing with the Shapiro Wilk test. Further stratification was performed using the Post-Hoc Tukey’s test. Here, p values of ≤0.05 were considered significant.

**Figure 3.** The panel of spectrophotometer showing ΔE value.

**3. Results**

The color stability of the dental composites Omnichroma (OM) and Filtek (FT) was assessed using a spectrophotometer (Vita Easyshade®V Compact Vita, Zahnfabrik, Bad Sackingen, Germany) after immersion in three different commonly used beverages, viz. Pepsi, coffee and milk tea. The lowest ΔE value was observed in OM-milk tea (mean ΔE 1.16 ± 0.30) group, while the highest ΔE value was observed in the FT-coffee group (8.50 ± 3.22).

Upon comparison between OM-Pepsi and FT-Pepsi, no statistically significant difference in ΔE value was observed in all composite shades (p > 0.05) (Table 2). Moreover, immersion in Pepsi had no significant influence on the color stability of all shades of the composite, although OM showed lower color stability and stain resistance than FT.

In the coffee group, FT showed higher ΔE than OM for shades A2 (3M-7.16 ± 4.21; OM 5.34 ± 3.32), A3 (3M-7.60 ± 2.62; OM-5.94 ± 1.45), B2 (3M-7.26 ± 1.02; OM-5.54 ± 2.06), and B3 (3M-8.50 ± 3.22; OM-6.54 ± 1.63). There was no statistically significant difference between OM-coffee and FT-coffee groups in all shades (A2 (p = 0.470), A3 (p = 0.251), B2 (p = 0.134), B3 (p = 0.260)) of the composite. The color stability OM–coffee and FT-coffee groups were also independent of the type of shade (p > 0.05) (Table 2).

Lastly, immersion in milk tea showed a statistically significant difference in A2 (p = 0.011), A3 (p = 0.001) and B2 (p = 0.000) shades of the OM-milk tea group in comparison to FT-milk tea group. Therefore, the color stability of OM was superior to FT. The differences between shades did not have a significant influence on ΔE values in OM-milk tea and FT-milk tea groups (p > 0.05).
Table 2. Mean difference in ΔE values of the samples before and after immersion in different beverages.

| Comparison among Groups | Shades | p Value  |
|-------------------------|--------|----------|
|                          | A2     | A3       | B2     | B3     |          |
|                          | Mean (SD) |          |        |        |          |
| Pepsi                   |        |          |        |        |          |
| Omnichroma              | 7.26 (2.64) | 6.26 (1.51) | 6.68 (1.41) | 4.58 (2.01) | 0.202   |
| Filtek Z250             | 5.14 (2.69) | 4.78 (2.54) | 3.92 (2.44) | 3.76 (1.56) | 0.754   |
| p-value                 | 0.245 | 0.296 | 0.060 | 0.493 |          |
| Coffee                  |        |          |        |        |          |
| Omnichroma              | 5.34 (3.32) | 5.94 (1.45) | 5.54 (2.06) | 6.54 (1.63) | 0.841   |
| Filtek Z250             | 7.16 (4.21) | 7.60 (2.62) | 7.26 (1.02) | 8.50 (3.22) | 0.891   |
| p-value                 | 0.470 | 0.251 | 0.134 | 0.260 |          |
| Milk Tea                |        |          |        |        |          |
| Omnichroma              | 1.42 (1.69) | 1.16 (0.30) | 1.94 (0.48) | 2.76 (0.96) | 0.104   |
| Filtek Z250             | 5.42 (2.13) | 5.30 (1.90) | 6.02 (1.32) | 2.82 (2.18) | 0.079   |
| p-value                 | 0.011 | 0.001 | 0.000 | 0.957 |          |

Following Post-Hoc Tukey’s analysis, significant differences were found in OM-Pepsi A1 shade compared to B3 shade (p = 0.046) and OM-milk tea A2 shade compared to B3 shade (p = 0.024). Similarly, in FT-milk tea, a statistically significant difference (p = 0.018) was found in B2 versus B3 shades (Table 3).

Table 3. Post-Hoc Analysis.

| Dependent Variable | Shades | Shades | Mean Difference | Std. Error | Sig.  |
|-------------------|--------|--------|-----------------|------------|-------|
|                   | A2     | B2     | B3              |            |       |
| OM Pepsi          |        |        |                 |            |       |
| A1                | 1.00000 | 0.58000 | 2.68000 *       | 1.23956    | 0.432 |
| B2                | 0.36000 | 1.22000 | 1.38000         | 1.48829    | 0.812 |
| FT Pepsi          |        |        |                 |            |       |
| A1                |        |        |                 |            |       |
| A2                |        |        |                 |            |       |
| B2                |        |        |                 |            |       |
| B3                |        |        |                 |            |       |

Following Post-Hoc Tukey’s analysis, significant differences were found in OM-Pepsi A1 shade compared to B3 shade (p = 0.046) and OM-milk tea A2 shade compared to B3 shade (p = 0.024). Similarly, in FT-milk tea, a statistically significant difference (p = 0.018) was found in B2 versus B3 shades (Table 3).
Table 3. Cont.

| Dependent Variable | Shades | Shades | Mean Difference | Std. Error | Sig. |
|--------------------|--------|--------|----------------|------------|------|
| OM Coffee          | A1     | A2     | −0.60000       | 1.41958    | 0.678|
|                    | B2     | −0.20000 | 1.41958     | 0.890       |      |
|                    | B3     | −1.20000 | 1.41958     | 0.410       |      |
|                    | A1     | 0.60000 | 1.41958     | 0.678       |      |
|                    | B2     | 0.40000 | 1.41958     | 0.782       |      |
|                    | B3     | −0.60000 | 1.41958    | 0.678       |      |
| B2                 | A1     | 0.20000 | 1.41958     | 0.890       |      |
|                    | B2     | −0.40000 | 1.41958    | 0.782       |      |
|                    | B3     | −1.00000 | 1.41958    | 0.491       |      |
| B3                 | A1     | 1.20000 | 1.41958     | 0.410       |      |
|                    | A2     | 0.60000 | 1.41958     | 0.678       |      |
|                    | B2     | 1.00000 | 1.41958     | 0.491       |      |
| A1                 | A2     | −0.44000 | 1.89937    | 0.820       |      |
|                    | B2     | −0.10000 | 1.89937    | 0.959       |      |
|                    | B3     | −1.34000 | 1.89937    | 0.491       |      |
| A2                 | A1     | 0.44000 | 1.89937     | 0.820       |      |
|                    | B2     | 0.34000 | 1.89937     | 0.860       |      |
|                    | B3     | −0.90000 | 1.89937    | 0.642       |      |
| B2                 | A1     | 0.10000 | 1.89937     | 0.959       |      |
|                    | A2     | −0.34000 | 1.89937    | 0.860       |      |
|                    | B3     | −1.24000 | 1.89937    | 0.523       |      |
| B3                 | A1     | 1.34000 | 1.89937     | 0.491       |      |
|                    | A2     | 0.90000 | 1.89937     | 0.642       |      |
|                    | B2     | 1.24000 | 1.89937     | 0.523       |      |
| OM Milk Tea        | A1     | A2     | 0.26000      | 0.64195    | 0.691|
|                    | B2     | −0.52000 | 0.64195    | 0.430       |      |
|                    | B3     | −1.34000 | 0.64195    | 0.053       |      |
| A2                 | A1     | −0.26000 | 0.64195    | 0.691       |      |
|                    | B2     | −0.78000 | 0.64195    | 0.242       |      |
|                    | B3     | −1.60000* | 0.64195  | 0.024       |      |
| OM Milk Tea        | A1     | 0.52000 | 0.64195     | 0.430       |      |
| OM Milk Tea        | A2     | 0.78000 | 0.64195     | 0.242       |      |
|                    | B3     | −0.82000 | 0.64195    | 0.220       |      |
| B3                 | A1     | 1.34000 | 0.64195     | 0.053       |      |
|                    | A2     | 1.60000* | 0.64195   | 0.024       |      |
|                    | B2     | 0.82000 | 0.64195     | 0.220       |      |
| B3                 | A1     | −2.60000* | 1.21227  | 0.018       |      |
|                    | A2     | −2.48000 | 1.21227    | 0.058       |      |
|                    | B2     | −3.20000* | 1.21227  | 0.018       |      |

* The mean difference is significant at the 0.05 level.
Mean changes in color variation $\Delta E$ from initial preoperative value (T0, before immersion) to final postoperative value (T14, after immersion at 14 days) in different beverages are shown for the Omnichroma composite in Figure 4 and Filtek Z250 composite in Figure 5.

![Graphical representation of mean changes in color ($\Delta E$) value of Omnichroma composite from T0 (Day 0) to T14 (Day 14).](image1)

**Figure 4.** Graphical representation of mean changes in color ($\Delta E$) value of Omnichroma composite from T0 (Day 0) to T14 (Day 14).

![Graphical representation of mean changes in color ($\Delta E$) value of Filtek Z250 composite from T0 (Day 0) to T14 (Day 14).](image2)

**Figure 5.** Graphical representation of mean changes in color ($\Delta E$) value of Filtek Z250 composite from T0 (Day 0) to T14 (Day 14).

4. Discussion

The study was conducted to evaluate the effects of different commonly consumed beverages, viz. milk tea, Pepsi, coffee, on the color stability of smart monochromatic and micro-hybrid composites. The outcome of this study showed a statistically significant difference in $A2$ ($p = 0.011$), $A3$ ($p = 0.001$) and $B2$ ($p = 0.000$) shades of the OM-milk tea group compared to the FT-milk tea group. Hence, the color stability of Omnichroma composite was superior to that of the Filtek Z250 composite.

Overall, Omnichroma showed less discoloration in the coffee and milk tea group compared to Filtek Z250m while Filtek Z250 showed less discoloration in the Pepsi group in comparison to Omnichroma for different beverages. This result could reflect the different chemical composition of both composite resins. The findings of our study are in agreement...
with Alhamdán et al. [16], who reported that Filtek Z250 showed more stain resistance than Omnichroma after immersion in the Cola beverage. The possible reason for this color change is based on the fact that the acidic pH of Cola has the potential to erode the surface texture of the resin restoration and increase its water sorption, which eventually affects the affinity of the resin to extrinsic stains. Moreover, Erta¸s et al. [19] also observed that the Filtek Z250 was more stain-resistant than the Supreme composite after immersion in different beverages. In contrast, Um and Ruyter [20] observed that despite having the lowest pH, Cola did not produce as much discoloration as coffee and milk tea. This observation may be due to the presence of yellow colorants in both coffee and tea, which have different polarities. Higher-polarity components, such as those present in milk tea, are eluted first, followed by the lower-polarity components present in coffee. Therefore, it is anticipated that discoloration by milk tea could be due to the adsorption of polar colorants onto the surface of the composite, whereas discoloration by coffee could be due to both the adsorption and absorption of colorants on the surface of the composite. This is further explained by the fact that the organic phase of the composite material allows for the penetration and absorption of colorants due to the polymer phase of the composite’s affinity for the yellow colorants in the coffee [21]. Furthermore, Bagheri et al. [22] also support the finding that coffee and tea produce more discoloration than cola or red wine.

The resin component in composite plays a crucial role in staining susceptibility. Studies have shown that urethane di methacrylate is more stain-resistant compared to bis-GMA due to its low water solubility and absorption [19,23]. Filtek Z250 contains three main components: bis-GMA, UDMA and bis-EMA. However, the TEGDMA (hydrophilic monomer) in Filtek Z250 was replaced with a blend of UDMA and bis-EMA, although it is still expected to absorb water; therefore, we observed highest $\Delta E$ value in the FiltekZ250 coffee group. On the other hand, the major component of Omnichroma is urethane dimethacrylate (UDMA), which is hydrophobic in nature and may be attributed to the lowest $\Delta E$ value, as observed in the Omnichroma milk tea group.

The long-term color stability of the composite after restoration is an area of concern for many clinicians. Previously, studies have reported that the 24 h of tooth sample immersion in different beverages is equal to approximately one month in vivo [19]. However, this was expected at an oral temperature of $37^\circ C$. The rise in temperature due to the hot beverages may expedite this process, so that temperatures higher than $51^\circ C$ are expected to simulate 12 months of in vivo environment compared to one-month in vitro at $37^\circ C$ [24]. Therefore, the 2 weeks of immersion in beverages in current study would correspond to an in vivo immersion of 14 months.

In this study, color measurements were taken using a spectrophotometer. The perception of color is a psychophysical phenomenon with high chances of variation between persons or the same person at different times. The color measurements made by a spectrophotometer have eliminated the possibility of human errors. Studies have shown that the human eye cannot detect color changes with a color alteration value of less than 3.5 [18,19]. In the present study, FT and OM showed color differences of more than 3.5, except for OM in the milk tea group. This indicates that the prolonged exposure of both the FT composite and OM composite are prone to staining by Pepsi and coffee. However, other chemical factors, such as the purity of the monomers and oligomers, initiators and inhibitors, type or concentration of activator, filler loading and color of the inorganic pigments, should also be considered [25].

The findings of this study must be seen in light of certain limitations. First, it is worth mentioning that this was an in vitro study, with inherent limitations when simulating an in vivo environment; therefore, the results should be interpreted cautiously. Nevertheless, the results of the current study can provide some understanding of how different beverages may affect the color stability of the OM composite, thus affecting the practitioners’ choice of material. Secondly, it is evident that the surface polishing and finish of the composite resin affect their color stability, translucency, and aesthetic outcome. However, due to time constraints, the effect of different finishing methods on the color stability of smart
monochromatic composite was not assessed. Lastly, the influence of ageing on the color stability of OM composite was not investigated. Hence, future studies are desirable to evaluate the effect of ageing on the long-term color stability of the OM composite.

Additionally, it has been demonstrated that other variables can be influenced by acidic drinks and foods, such as hardness [26] and flexural strength [27]. Therefore, further research is warranted considering these variables.

5. Conclusions

In summary, the immersion of teeth in beverages with a different pH and colorant showed apparent alterations in the color of both smart monochromatic and micro-hybrid composites. Hence, the type of resin composite material should be selected wisely, depending on the patient’s drinking and social habits.

Author Contributions: Conceptualization, M.A.A. and R.J.; methodology, M.A.A. and R.J.; software, F.V.; validation, M.A.A. and R.J.; formal analysis, R.J.; investigation, M.A.A. and R.J.; resources, M.A.A.; data curation, F.V.; writing—original draft preparation, M.A.A.; writing—review and editing, F.V. and R.J.; visualization, M.A.A.; supervision, F.V.; project administration, R.J.; funding acquisition, M.A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia [Project No. GRANT450].

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics review Committee) of King Faisal University (KFU-REC/2021-02-22).

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors are grateful to the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Al Ahsa, Saudi Arabia for funding this project.

Conflicts of Interest: The authors declare no conflict of interest.

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