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# *In vitro* Assessment of the Color Stability of Two Resin Composites

[1]Racha Joseph Hajj, [2]Lara Nasr, [1]Carlos Khairallah and [1]Louis Hardan

[1]*Department of Prosthodontics and Restorative Dentistry, Faculty of Dental Medicine, Saint Joseph University, Beirut, Lebanon*
[2]*Cranio-Facial Research Laboratory, Faculty of Dental Medicine, Saint Joseph University, Beirut, Lebanon*

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Corresponding Author:
Racha Joseph Hajj
Department of Prosthodontics and Restorative Dentistry,
Faculty of Dental Medicine,
Saint Joseph University, Beirut,
Lebanon
Email: rahajj94@gmail.com

**Abstract:** This *in vitro* study aims to evaluate the effects of thermocycling and immersion in common dietary colorants on the color stability of two resin composites. 80 disk-shaped specimens divided into 2 groups of 40 each, were prepared using a plexiglass mold with the desired dimensions, polished, and stored in 37°C distilled water for 24 h. Thermocycling (10,000 cycles) was applied to all specimens. Color shades were recorded before and after thermocycling, 24 h, 3 days, and 6 days after immersion in colorants. Thermocycling has shown fewer color changes than immersion in colorants. The omnichroma led to overall higher color changes than 3M Filtek Z350 when immersed in all the colorants. Within the limitations of this study, the following conclusions were drawn: Thermocycling slightly affects the color stability of resin composites compared to immersion in colorants. The staining ability of resin composites is affected by the composite's brand, the type of solution, and the duration of immersion. Omnichroma has shown less color stability over time (6 months) compared to Filtek 3M Z350 XT when immersed in different solutions.

**Keywords:** Aging, Omnichroma, Smart Chromatic Technology, Spectrophotometer, Thermocycling

## Introduction

The field of restorative and cosmetic dentistry is evolving quickly in terms of new and improved materials to meet the growing need and desire for a more natural-like appearance of dentition; Composite restorations and new formulations of bonding agents have made composites more versatile.

Resin composites and novel bonding agent compositions have resulted in restorations being more aesthetic and adaptable (Auster, 2019). From the middle of the 20$^{th}$ century and to enhance dental composite properties, innovations and developments in its components such as monomers, minerals, micro /macro, and nanoparticles were done.

By definition, a dental composite is known as a three-dimensional compound including a resin matrix (basically composed of a mixture of Bis-GMA, Triethylene Glycol Dimethacrylate (TEGDMA), a Hydroxyethyl Methacrylate (HEMA), and Urethane Dimethacrylate (UDMA) (Phillips *et al*., 1973) inorganic fillers (such as silica and quartz which plays an important role in the physical and mechanical properties of a resin composite providing higher stiffness and increased radio-opacity (Munksgaard *et al*., 1987; Van Dijken *et al*., 1989) and additives (initiators, catalyst systems, viscosity controllers, pigments….).

Coupling agent: In general, consisting of organic silane such as 3-methacryloxypropyltrimethoxysilane and 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP). They chemically link the fillers to the resin matrix and therefore, enhance the bonding of these two matrices (Rebholz-Zaribaf and Özcan, 2017).

Polymerization of dental composites is initiated and activated chemically (ex: Tertiary amine molecule) or light-activated (ex: Camphorquinone molecule) (Santini *et al*., 2013).

There are many types of dental composites in the market, divided into many categories. The most used classification is the one designed by Lutz and Philipes in 1983 based on the filler particle size (Randolph *et al*., 2016; Habib *et al*., 2018). Composites can be classified into macro-filled, micro-filled, hybrids, nanocomposites, and the latest generation: The nanohybrids, most used nowadays (Sideridou *et al*., 2009; Phillips *et al*., 1973; Mitra *et al*., 2003) properties of dental composites are divided into mechanical and optical characteristics.

Mechanical properties such as fracture toughness, modulus of elasticity, hardness, etc... will not be discussed in this study, whereas optical properties such as color stability, color match, shape, and texture are important factors to talk about since this study relies on the comparison of color stability between two resin composites.

Since the mouth is a constantly changing habitat, the color stability of any esthetic material can be compromised by the presence of saliva, bacteria, and frequent consumption of colorful foods (Menon *et al*., 2019).

To be classified as an esthetic restorative material, dental composites should retain color and polish over a long period of time. Nowadays, despite the property's improvement of dental composites, discoloration remains to be a major long-term clinical problem (Menon *et al*., 2019).

Changes in color can be the result of intrinsic discoloration due to physicochemical reactions in the deep portions of the restoration or the result of extrinsic discoloration due to the accumulation of plaque and stains such as tea, coffee, beverages, … (Ceci *et al*., 2017) depending on several factors, such as the staining agent, the time of immersion, contact time with colorants, surface roughness and the type of composite resin used. (Barutcigil and Yıldız, 2012).

Different factors can be responsible for affecting the color stability in composite restorations such as the resin matrix, dimensions of filler particles, depth of polymerization, and coloring agent (Patel *et al*., 2004).

Discoloration of tooth-colored resin-based materials can be induced by intrinsic or extrinsic factors (Ibrahim *et al*., 2019). Intrinsic variables include incomplete polymerization which leaves unreacted monomers, resulting in discoloration by aging and subsequent reactions with other substances; Composition of composite resins: According to studies, resin materials that use Urethane Dimethacrylate (UDMA) as a matrix have better color stability than resin materials that use Bis GMA dimethacrylate as a matrix. The UDMA matrix results in lower viscosity and lower water absorption (Badra *et al*., 2005); fillers (the larger filler particle size resulted in rougher surfaces (Vichi *et al*., 2004) allowing higher stain coloration and the photoinitiator: It is well recognized that polymerization efficiency can affect discoloration since the higher the degree of conversion, the fewer residual monomers are available to generate colored degradation products (Haselton *et al*., 2005).

Extrinsic factors (Rodrigues *et al*., 2012) include types of food colorants and immersion time: Many types of colorants that have the potential to cause color changes in dental materials have been studied over the years, including tea, coffee, beverages, grape/cherry juice, wine, nicotine and mouth rinses containing disinfectant agents (Catelan *et al*., 2011).

And finally, the surface finish: Polishing and finishing are important steps that enhance both the esthetics and longevity of resin composite restorations (Nazish, 2013).

Rough surfaces of restorative materials tend to accumulate more plaque and absorb more water and food colorants. Whereas smooth-finished restorations result in better color stability over time. The surface roughness of resins is due to irregularly arranged inorganic filler particles and hence gets easily stained by mechanical adsorption (Eliezer *et al*., 2020).

Discoloration can be assessed visually and using instrumental techniques. Instrumental techniques eliminate the subjective interpretation inherent in visual color comparison. Therefore, spectrophotometers and colorimeters are widely used tools to detect color changes in dental restorative materials (Menon *et al*., 2019).

While in the field of direct restorations, the biggest dentist challenge is to replicate the appearance and color of teeth to their closest initial aspect, and according to previous studies, color match is considered subjective, relying on many factors such as the light source and the observer and differences among practitioners concerning the same teeth shade matching occur every day (Hardan *et al*., 2022). Hence the demand for aesthetic direct restorations has increased in the last two decades and therefore, composites with higher mechanical strength and newer optical technologies were introduced in the market.

One of the newest technologies introduced in 2019 by Tokuyama Dental, Japan, is the smart chromatic technology, which uses equally sized spherical filler particles in a dental composite product: The Omnichroma, Tokuyama Dental, Japan.

Omnichroma, with its unique smart chromatic technology, is the first shade-matching composite that recently gained a lot of popularity (Baroudi and Rodrigues, 2015). How to explain smart chromatic technology? Before going to the technology, itself, let us talk about the color-producing phenomenon.

First, color is defined as the wavelength of light that enters our eyes. Human teeth fall in the red-to-yellow color space Baroudi and Rodrigues (2015).

There are two types of color-producing phenomena:

1) Chemical mechanism

Molecules in a dental composite reflect wavelengths. It is the most common form of color visible to us. Almost all dental composites today rely on the chemical color of added pigments and dyes.

2) Structural mechanism

The structure of the resin composite amplifies or weakens different wavelengths. OMNICHROMA is the first dental composite that relies on structural color as the main color mechanism (Baroudi and Rodrigues, 2015).

It does not rely on added dyes or pigments but on its smart chromatic technology which relies on the size and shape of the fillers: The composite's 260 nm spherical fillers are the exact size and shape needed to generate red-to-yellow color the range found in human teeth. As light passes through the fillers, it produces this red-to-yellow spectrum and combines with the reflected color of surrounding dentition to create a perfectly seamless match (Eliezer *et al*., 2020).

This prospective *in vitro* study aims to evaluate and assess the effects of thermocycling and common dietary colorants on color stability of a Nano filled composite resin: (Z350, 3M ESPE, St PAUL, MN, USA) and a monochromatic resin composite: (Omnichroma, TOKOYAMA, JAPAN) on 80 disk shaped composites (40 from each type) at baseline, after thermocycling, after 1, 3 and 6 months of *in vitro* immersion in dietary colorants.

The null Hypothesis (H0) was that thermocycling and immersion in colorants do not affect the color stability of the two resin composites and that the staining ability of the evaluated resin composites would not differ according to the composite's brand, the type of staining solution and the duration of storage in beverages.

The alternative Hypothesis (H1) was that thermocycling and immersion in colorants affect the color stability of the two resin composites and that the staining ability of the evaluated resin composites differs according to the composite's brand, the type of staining solution and the duration of storage in beverages.

## Materials and Methods

80 disk-shaped material specimens (10 mm diameter and 2 mm thickness) were prepared using a plexiglass mold with the desired dimensions and polished using the super snap polishing kit by Shofu Dental.

The eighty specimens were polished and then divided into two groups numbered 1-40 each. Figures 1-3 each composite composition is described in Table 1.

The composite material was delivered directly from the syringe into the ring on top of the glass plate. The material was condensed using a Teflon-coated composite filling instrument (*OptraSculpt, Ivoclar), and* a glass plate was then placed onto the plexi mold and pressed on the top surface of the material. The tip of a light-curing unit (LED light device Curing Pen, Eighteeth) was positioned as close as possible without touching the material. The composites were cured for 40 s using a light-curing unit. To ensure adequate curing, the specimens were cured for another 20 s after the glass plate was removed. The composite disks were polished using a super-snap polishing system (*Super Snap*, *Shofu Dental*) following the manufacturer's recommendations (Fig. 4).


**Fig. 1:** Disks numbering


**Fig. 2:** Omnichroma disks


**Fig. 3:** Filtek 3M Z350

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**Table 1:** Composites composition

| Resin Composite | Composition | Manufacturer/Fabricant |
|---|---|---|
| Omnichroma | Matrix: UDMA- TEGDMA<br>Filler: Uniform-sized supra-Nano spherical filler<br>(260 nm spherical $SiO_2$-$ZrO_2$) | Tokoyama Dental, Japan |
| Filtek Z 350 XT | Matrix: Bis-GMA, UDMA, TEGDMA, bis-EMA, PEGDMA<br>Filler: Combination of non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non-aggregated 4-11 nm zirconia filler and aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4-11 nm zirconia particles (Munksgaard *et al*., 1987) | 3M ESPE, St PAUL, MN, USA |

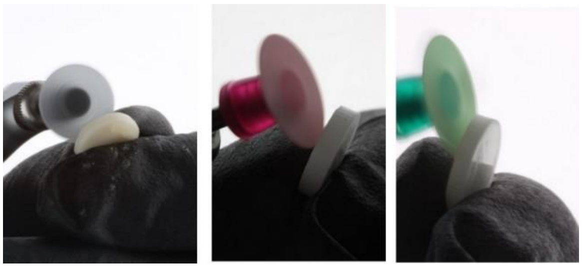

**Fig. 4:** Polishing system

**Fig. 5:** Different solutions

**Fig. 6:** Storage solutions

When all the specimens were ready, they are stored in 37°C distilled water for 24 h and prior to thermocycling and testing in different staining agents, color shades of each group were recorded using the Vita Easyshade spectrophotometer (Vita Easyshade Compact Vita, Zahnfabrik, Bad Sackingen, Germany) that was calibrated in accordance with the National Institute of Standards and Technology (NIST) tiles. Color measurements were performed by positioning the specimen on a white background to prevent potential absorption effects.

After shade measurements, thermocycling was then applied to all specimens using the thermocycling machine present in the laboratory of the faculty (1200 *Thermocycler: SD, Mechatronick, Germany*). 10,000 cycles were applied which according to the literature, is equivalent to around 1 year in a patient's mouth (Mitra *et al*., 2003).

After thermocycling, shade measurements were taken again before immersion in different agents.

### *Solutions Preparation (Figure 5)*

1) Distilled water as control (solution 0.9% NaCl)
2) Coffee solution: 10 g of coffee was added to 1000 mL of water and boiled for 2 min (Café Najjar, Lebanon)
3) Red wine (Château Ksara, Cuvée de Troisième Millénaire, Bekaa Valley 2008)
4) Cola (Pepsi cola)
5) Tea (Lipton tea)

Previously, studies have reported that 24 h of tooth immersion in different agents is approximately equivalent to one month *in vivo* (Takahashi *et al*., 2008). However, this was expected at an oral temperature of 37*C. The rise in temperature due to the hot beverages may expedite this process so that temperatures higher than 51*C are expected to simulate 12 months of *in vivo* environment compared to one month *in vitro* at 37*C (Rueggeberg, 2002). Therefore, the 6 days of immersion in beverages in this study would correspond to an *in vivo* immersion of 6 months.

Concerning immersion of specimens in liquids, each group was divided into 5 subdivisions according to storage solution/staining agent: (1) Red wine, (2) Tea, (3) Distilled water, (4) coffee, and (5) Pepsi. Figure 6 Color measurements were taken after the first day (T1), the third day (T3), and the last day (T6).

### *Shade and Color Stability Measurements*

Before each measurement, disks were rinsed in distilled water. Excess water on the surfaces was removed with tissue papers and teeth were allowed to dry.

The color of the specimens was measured using the Vita easy shade spectrophotometer (Vita Easyshade®V Compact Vita, Zahnfabrik, Bad Sackingen, Germany) against a white background and was calibrated according to the manufacturer's instructions by using the supplied white calibration standard.

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**Table 2:** NBC units

| NBC unit | Critical remarks on color differences | |
|---|---|---|
| 1.-0.5 | Trace | Extremely slight change |
| 0.5-1.5 | Slight | Slight change |
| 1.5-3.0 | Noticeable | Perceivable change |
| 3.0-6.0 | Appreciable | Marked change |
| 6.0-12 | Much | Extremely marked change |
| 12.0 or more | Very much | Change to another color |

The average value of these three readings was automatically calculated and recorded. Color changes before and after thermocycling and colorant immersion were characterized using the Commission International d'Eclairage L*a*b* color space (CIE L*a*b*) for classifying and correlating color numerically, with the ability to calculate the difference between two colors using a standardized color formulation.

The (CIE L*a*b*) space is currently one of the most popular and widely used color spaces and it is well suited for the determination of small color differences. In this three-dimensional color space, the three axes are namely L*, a*, and b*. The L* value is a measure of the whiteness or brightness of an object. The a* value is a measure of redness (positive a*) or greenness (negative a*). The b* value is a measure of yellowness (positive b*) or blueness (negative b*). The advantage of the CIE L*a*b* system is that color differences can be expressed in units that can be related to visual perception and clinical significance (Asmussen and Peutzfeldt, 1990).

Total color differences are expressed by the formula:

$$\Delta E^* \left( (\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2 \right)^{1/2}$$

where, $\Delta L^*$, $\Delta a^*$, $\Delta b^*$ are the differences in $L^*$, $a^*$ and $b^*$ values before (T0) and after immersion.

To relate the amount of color change ($\Delta E^*$) recorded by the spectrophotometer to a clinical environment, the data were converted to National Bureau of Standards units (NBS units) through the equation, NBS units $= \Delta E^* \times 0.92$, where critical remarks of color differences as expressed in terms of NBS units. These values are shown in the table (Peutzfeldt and Asmussen, 1992) (Table 2).

## Results

### *Statistical Analysis*

Data were collected on Excel sheets before being transferred to IBM SPSS Statistics for Windows (Version 26) (IBM Corp., Armonk, NY, USA) for statistical analyses. All tests were two-tailed and a p-value of less than 0.05 was considered statistically significant. Quantitative variables were summarized and presented as means ± standard deviations. Shapiro-Wilk test was used to evaluate the normality of distribution of the continuous variables (ΔE* and NBS) when at least one group comprised less than 30 specimens. To compare ΔE* values over time (right after thermocycling, 24 h, 3 days, and 6 days after immersion), the repeated-measures ANOVA and Friedman's test were used followed by Bonferroni post-hoc tests for multiple comparisons. Student t-test and Mann-Whitney U test were used to compare ΔE* values (at every time point) between resin composites and immersion solutions.

Table 3 displays the result of the comparisons between ΔE* means according to the different time points. The highest mean was recorded 24 h after immersion and the lowest mean was observed right after thermocycling. Color stability was noticed between 3 days and 6 days after immersion (the difference in ΔE* means was not statistically significant). Means of NBC values were also displayed in this table in order to relate the amount of color change to the clinical environment; after thermocycling, the difference in color was extremely remarkable, whereas the other values indicated a change to another color 24 h, 3 days and 6 days after immersion.

Concerning immersion in the different colorants, to compare ΔE* means (at every time point) between the different immersion solutions (Pepsi®, tea, red wine, coffee, and distilled water), the Kruskal-Wallis test was used and groups were compared right after thermocycling to evaluate the initial comparability and they proved to have statistically similar ΔE* means.

Results of the comparison of ΔE* means at every time point between the immersion solutions within the Omnichroma group, are shown in Table 4. Before immersion, groups were comparable and the highest color variation was observed in specimens that were immersed in red wine. In the control group, ΔE* means did not significantly change 1, 3, and 6 days after immersion compared to the $\Delta E^*$ mean right after thermocycling. The mean of $\Delta E^*$ 6 days after immersion in Pepsi was statistically similar to that of the control group.

Results of the comparison of ΔE* means at every time point between the immersion solutions within the 3M Z350 group, are shown in Table 5. Similarly, to the Omnichroma group, the highest color variation was observed in the red wine group, and the ΔE* means of the red wine group at all-time points (1, 3, and 6 days after immersion) were statistically significantly higher than those of the Pepsi and distilled water groups. Pepsi, tea, and coffee do not seem to significantly increase ΔE* over time after immersion.

**Table 3:** Comparison of ΔE* [compared to baseline] and NBC means between the different time points, regardless of resin composites, polishing, and immersion solutions

| | ΔE* (mean ± SD) | NBS (mean ± SD) | p-value |
|---|---|---|---|
| After thermocycling | 7.55±6.61$^{C}$ | 6.95±6.09$^{C}$ | |
| 24 h after immersion | 35.07±16.68$^{A}$ | 32.26±15.34$^{A}$ | |
| 3 days after immersion | 29.85±17.13$^{B}$ | 27.46±15.76$^{B}$ | <0.001* |
| 6 days after immersion | 29.78±17.61$^{B}$ | 27.40±16.2$^{B}$ | |

SD = Standard Deviation; *p<0.05; different uppercase superscript letters indicate statistically significant differences between values according to time

**Table 4:** Comparison of ΔE* means [compared to baseline] at every time point between immersion solutions and between time points within each immersion solution in the Omnichroma group

| | 7.98±3.49$^{Ba}$ | 13.49±5.86$^{Ba}$ | 11.62±6.39$^{Ba}$ | 9.33±6.27$^{Ca}$ | 10.65±8.37$^{Aa}$ | |
|---|---|---|---|---|---|---|
| | Pepsi® (n = 8) | Tea (n = 8) | Red wine (n = 8) | Coffee (n = 8) | Distilled water (n = 8) | 0.504 |
| After thermocycling | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | p-value |
| 24 h after immersion | 10.53±3.89$^{ABb}$ | 13.68±5.91$^{Bab}$ | 22.87±6.9$^{ABa}$ | 1.96±6.68$^{BCab}$ | 7.41±4.05$^{Ab}$ | <0.001* |
| 3 days after immersion | 10.84±2.98$^{ABb}$ | 18.38±7.38$^{ABab}$ | 34.03±16.62$^{Aa}$ | 21.01±8.69$^{ABab}$ | 12.84±7.24$^{Ab}$ | 0.001* |
| 6 days after immersion | 11.76±3.04$^{Abc}$ | 23.44±14.17$^{Aab}$ | 28.73±5.98$^{Aa}$ | 23.47±8.98$^{Aab}$ | 9.57±4.56$^{Ac}$ | <0.001* |
| p-value | 0.018* | <0.001* | <0.001* | <0.001* | 0.290 | - |

SD = Standard Deviation; *p<0.05; different uppercase superscript letters indicate statistically significant differences between ΔE* means according to time within each group; different lowercase superscript letters indicate statistically significant differences between ΔE* means at each time according to immersion solutions

**Table 5:** Comparison of ΔE* means [compared to baseline] at every time point between immersion solutions and between time points within each immersion solution in the Filtek 3M group

| | 5.54±4.17$^{Aa}$ | 9.67±5.9$^{Aa}$ | 6.88±5.23$^{Ba}$ | 6.96±4.85$^{Ba}$ | 7.01±5.55$^{Aa}$ | |
|---|---|---|---|---|---|---|
| | Pepsi® (n = 8) | Tea (n = 8) | Red wine (n = 8) | Coffee (n = 8) | Distilled water (n = 8) | 0.735 |
| After thermocycling | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | p-value |
| 24 h after immersion | 7.5±1.1$^{Ab}$ | 8.93±6.27$^{Ab}$ | 24.07±10.84$^{ABa}$ | 8.87±1.66$^{ABab}$ | 4.93±2.45$^{Ab}$ | <0.001* |
| 3 days after immersion | 7.6±1.6$^{Ab}$ | 14.9±15.66$^{Aab}$ | 33.68±15.57$^{Aa}$ | 12.46±4.4$^{ABab}$ | 6.77±2.02$^{Ab}$ | <0.001* |
| 6 days after immersion | 8.12±1.4$^{Ab}$ | 12.65±9.05$^{Aab}$ | 35.05±17.96$^{Aa}$ | 13.07±3.48$^{Aab}$ | 8.68±4.46$^{Ab}$ | <0.001* |
| p-value | 0.092 | 0.136 | <0.001* | 0.009* | 0.145 | - |

SD = Standard Deviation; *p<0.05; different uppercase superscript letters indicate statistically significant differences between ΔE* means according to time within each group; different lowercase superscript letters indicate statistically significant differences between ΔE* means at each time according to immersion solutions

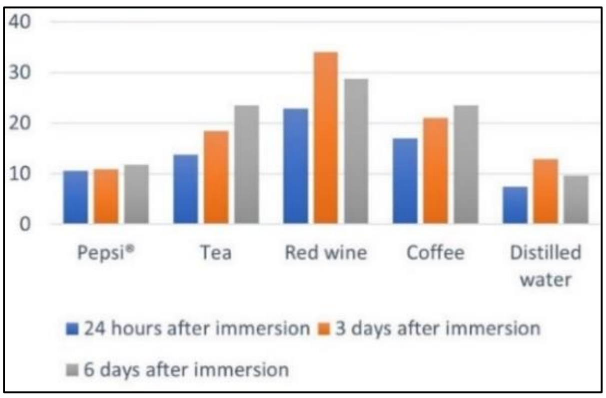


**Fig. 7:** ΔE means of omnichroma when stored in different solutions after 1, 3, and 6 days

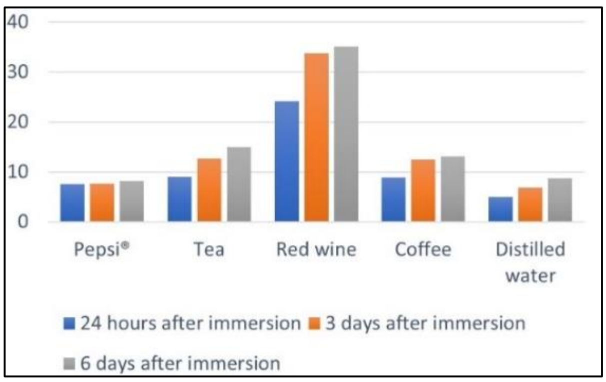


**Fig. 8:** ΔE means of Filtek 3M Z350 when stored in different solutions after 1, 3, and 6 days

In order to visually better compare the results of immersion in different solutions, tables were converted into charts (Figs. 7-8).

## Discussion

The dynamic nature of the oral environment with constant changes in pH, stress, and temperature may significantly influence the color stability of esthetic restorative materials.

In this study the aim was to evaluate and assess the effects of thermocycling and common dietary colorants on the color stability of a Nano filled composite resin: (Z350, 3M ESPE, St PAUL, MN, USA) and a monochromatic resin composite: (Omnichroma, TOKOYAMA, JAPAN) on 80 disk shaped composites (40 from each brand) at baseline, after thermocycling, after 1 month, 3 months and 6 months of *in vitro* immersion in dietary colorants.

For this purpose, the tested resin composites were submerged for 24 h, 3 days, and 6 days in colorants since in the oral cavity, dental composites remain exposed to various staining solutions over a long period of time at varying temperatures.

Color perception is a subjective issue, depends on the observer's skill, and may differ from one observer to another. To overcome the errors that may result, data were recorded and color measured in the CIE L*A*B* universal system.

Omnichroma, being a special single shade composite relying on a smart chromatic technology has undergone, till now, different *in vitro* and vivo studies to investigate its color adjustment potential and optical properties. Yet, according to our knowledge, a lot of research and investigations still need to be done regarding this composite.

Concerning the Filtek 3M Z350 universal nanocomposite and despite the big variety of matrix systems and composites, this composite is considered one of the most investigated composite materials, especially regarding its color stability. (Kim and Park, 2018; Poggio *et al*., 2016). Concerning the shade, the A2B shade was used in this study since it’s considered the most used shade clinically (Rodrigues *et al*., 2012).

For the *in vitro* evaluation of the color stability, various artificial aging techniques can be used such as thermocycling and immersion in different solutions (Rocha *et al*., 2017).

In this study, thermocycling was applied to all specimens using the thermocycling machine present in the laboratory of the Research Center of St. Joseph University, Beirut (1200 Thermocycler: SD, Mechatronic, Germany). 10,000 cycles were applied which according to the literature, is equivalent to around 1 year in a patient’s mouth (Mitra *et al*., 2003) and 5 storage media were used in immersion: Distilled water as control solution, red wine, cola, tea and coffee as representative of cold and hot drinks that may stain composite restorations. Each day, according to the literature, is equivalent to 1 month in a patient’s mouth.

Table 3, we can conclude that regardless of the composite brand and immersion solution, the lowest color change was seen directly after thermocycling, whereas the highest color change was noticed 24 h after immersion.

The results are in concordance with other studies done by Lee *et al.* (2011); El-Rashidy *et al.* (2022); Yu and Lee (2009); Wang and Zheng (2021) that showed slight changes in the color of resin composites before and after thermocycling and that aging by immersion resulted in higher color changes compared to thermocycling.

Since thermocycling relies on thermal changes and water absorption, it can be said that the internal and external structures of resin composites are not much affected by these two factors and therefore, small color changes may appear compared to immersion in colorants.

Distilled water which does not have any coloring agents served as a control in the present study and presented the lowest $\Delta E$ means among all the staining solutions. Although it does not contain any staining agent, changes in color were seen. In agreement with our study, other studies did respectively by Malekipour *et al.* (2012); Ertas *et al.* (2006); Cabadağ and Misilli (2022) have shown color changes of disks after immersion in distilled water with the lowest delta E means among all the solutions.

The change in color in distilled water despite the absence of pigments, can be explained by water absorption of the organic matrix over time and therefore leading to the degradation of the matrix's structure over time. Similarly, to our study, (Erdemir *et al*., 2012) in their article published in 2012 have shown a significant color change of resin composites after 6 months of immersion in distilled water. In contrast, red wine caused the highest discoloration among all immersion media in both resin composite materials. It is in accordance with other studies that have shown the highest color changes in resin composites when immersed in red wine compared to other groups (Domingos *et al*., 2011; Schroeder *et al*., 2019).

This may be attributed to its high staining effect and high concentration of tannin and anthocyanin water-soluble pigments from grapes (Domingos *et al*., 2011; Aydın *et al*., 2020).

In addition, the alcohol % in red wine may degrade the resin composite’s surface resulting in a rough surface favoring more pigment deposition and therefore higher risk of discoloration (Aydın *et al*., 2020).

In both groups and in agreement with other studies, cola led to the lowest changes after distilled water. The color changes of disks stored in cola were almost similar to the color changes of the ones stored in distilled water.

Cola had the lowest PH among the other mediums and it has been shown that this acidic environment may affect the composite's matrix externally by damaging the surface integrity of resin composites and internally by dislocating the filler particle as a result of chemical interaction with organic matrix (Quek *et al*., 2018). Despite the acidic effect of this solution on the resin matrix, low color changes were seen and this may be due, according to Domingos *et al*. (2011) to the absence of yellow colorant in its composition which is more abundant in tea and coffee (Aydın *et al*., 2020).

Coffee is composed of acidic agents such as chlorogenic acid and protocatechuic acid which are able to degrade the composite matrix and since coffee contains yellow stains such as gallic acid and caffeine, they will be absorbed and lead to color changes in the composite in contrary to cola, which also degrade the composite matrix by its acidic agents such as phosphoric acid but does not contain yellow pigments and therefore does not lead to major color changes as said by Domingos *et al*. (2011); Abdelhamed *et al*. (2022).

Concerning the tea medium, statistically color changes were seen in the Omnichroma group and not in the 3M Z350. Similarly, for the coffee solution, compared to the Omnichroma, the 3M Z350 has shown significantly lower changes in $\Delta E$ means. It may be attributed to the ability of the tea molecules to penetrate deep inside the spherical particles of the Omnichroma.

Although both materials suffered from color instability, the Filtek Z350 XT displayed overall lower discoloration than Omnichroma after aging in the different beverages.

This is in agreement with a study done by El Rashidi *et al.* (2022) which found less discoloration in the Filtek Z350 disks compared to Omnichroma disks after immersion in different solutions.

It may be justified by the material's composition; The Filtek Z350 XT is composed of Bis-EMA higher molecular weight monomers, characterized by its high degree of conversion as well as hydrophobicity and therefore, low water absorption (Gajewski *et al*., 2012), in addition to Bis-GMA which increase the polymer crosslinking density and consequently lower the infiltration of colorants and water (Hamdy, 2021).

In Contrast, the Omnichroma matrix is mainly composed of UDMA and TEGDMA lower molecular weight monomers which have been reported as hydrophilic monomers, thus, increasing water and drinks absorption and affecting damaging the color stability (Gajewski *et al*., 2012).

Abdelhamed *et al*. in their study comparing the Omnichroma composite to the Essentia GC composites have also less color stability in the Omnichroma than The Essentia composite (Abdelhamed *et al*., 2022).

According to the results of this study, the null hypothesis was rejected, and aging through thermocycling and immersion in colorants affect the color stability of resin composites over time, and the staining ability of resin composites is affected by the composite's brand, type of the solution and the duration of immersion.

And finally, Omnichroma has shown less color stability over time compared to Filtek 3M Z350 XT when immersed in all of the solutions.

## Conclusion

At the end of this study, you might be asking yourselves to use or not to use the omnichroma and its unique smart chromatic technology to facilitate your daily practice in esthetic dentistry. Well, the answer is that technology is moving very fast, paving the way to excellence in dentistry. But we cannot disregard the risks of technology without basing it on solid research in order to properly use it on human teeth.

Till now there isn't any conclusive answer to this question, both composites have been tested and proven to provide superior performance and each has its own set of strengths and weaknesses.

Within the limitations of this study, the following conclusions were drawn:

1- Thermocycling slightly affects the color stability of resin composites compared to immersion in colorants
2- The staining ability of resin composites is affected by the composite's brand, the type of solution and the duration of immersion
3- Omnichroma has shown less color stability over time (6 months) compared to Filtek 3M Z350 XT when immersed in different solutions

For sure this study has its own limitations and furthermore, long-term clinical *in vivo* trials and *in vitro* trials adding brushing for example, or artificial saliva is necessary to determine the color stability over time of these composites in the oral cavity and how this smart chromatic technology really works on human teeth.

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## Author's Contributions

**Racha Joseph Hajj:** *In vitro* study and written the article.

**Lara Nasr:** Statistics and results.

**Carlos Khairallah and Louis Hardan:** Reviewed the article.

## Ethics

Authors address no ethical issues that may arise after the publication of this manuscript.

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