ORIGINAL RESEARCH

Color Stability of Bioactive Restorative Material vs Nanohybrid Resin Composite: An *In Vitro* Study

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Received on: 17 February 2024; *Accepted on:* 15 March 2024; *Published on:* 19 April 2024

Abstract

Aim: This study aimed to assess the color stability of bioactive restorative materials vs nanohybrid resin composites after 3 months of immersion in three frequently consumed beverages.

Materials and methods: Thirty disk-shaped specimens of Giomer dental restorative material (Shofu, Japan) and nanohybrid resin composite (Tokuyama, Japan) were performed using a Teflon mold. Super-Snap system (Shofu, Japan) was utilized to finish and polish the specimens to be preserved for 24 hours in distilled water at 37°C. The samples had been divided into three subgroups (Coffee, tea, Pepsi) ($n = 5$). The initially displayed color measurements of the samples were performed using a spectrophotometer (VITA Easyshade® V). After 7 days, 30 days, and 90 days, color measurements were repeated, and the Δ*E* of each sample was estimated. Δ*E* of each sample was calculated.

Results: The Giomer group showed statistically significant higher Δ*E* values than the nanohybrid resin composite where the *p*-value was ≤0.0001. Tea subgroup showed the highest statistically significant Δ*E* values in both groups where the *p*-value was ≤ 0.0001. The highest statistically significant color change was recorded at 3 months.

Conclusion: The color of bioactive restorative material is less stable if compared with nanohybrid resin composite.

Clinical significance: As tea and coffee are popular beverages, particularly in Middle Eastern nations, dentists must advise patients about the color change of resin restorations. Patients are advised to brush their teeth immediately after consuming these beverages.

Keywords: Color, Color change, Color stability, Composite, Nanohybrid composite resins, Resin composite.

The Journal of Contemporary Dental Practice (2024): 10.5005/jp-journals-10024-3654

Introduction

A person's smile significantly impacts their appearance and is frequently a good indicator of their social and psychological health. Esthetics, as a current necessity, frequently inspires individuals to seek dental care. Resin-based composites are becoming the main materials of choice for esthetic restorations because of the growing need for an attractive appearance and due to their advantages of being functionally convenient, having a wide variety of colors available, excellently compatible with biological systems, and restoring teeth' appearance in their natural state.[1]

The continual modifications and advancement in the sector of esthetic restorative materials have resulted in the development of several new-generation resin composites.[2] Advancement in restorative biomaterials has focused on producing hybrid restorative materials. These bioactive materials, like Giomers, are among the most recent advancements in dental materials that release fluoride.[3]

The durability of esthetic restorations largely depends on the material's stain resistance. Resin composite restorations get stained in the oral cavity for a variety of reasons. The internal discoloration is caused by physical and chemical processes, whereas external discoloration is induced by the ingestion of various coloring agents.[4,5]

Soft drinks and tea consumption have increased significantly because of habit changes. These solutions cause staining in tooth structure and esthetic restorative materials reducing their lifespan and durability which can have a direct impact on patient satisfaction therefore color stability of esthetic restorations is a crucial property to consider. However, manufacturers provide minimal information about resin composite staining potential, and there is a shortage of scientific data demonstrating clinical color stability.[6] The current study was conducted to assess the color stability of bioactive restorative material vs nanohybrid resin composite. The first null hypothesis was that the type of resin composite would not affect the color stability. The second null hypothesis was that storage in beverages and duration of storage would not affect the color stability of resin composite materials.

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How to cite this article: Saber EH, Abielhassan MH, Abed YA, *et al*. Color Stability of Bioactive Restorative Material vs Nanohybrid Resin Composite: An *In Vitro* Study. J Contemp Dent Pract 2024;25(3): 221–225.

Source of support: Nil

Conflict of interest: None

Materials and Methods

Tested Materials

The materials utilized in this study are mentioned in Table 1.

Study Design

An *in vitro* study was conducted in the Conservative Dentistry Department, Faculty of Dentistry, October 6 University, Egypt, and carried out from December 2022 till March 2023. The protocol of this study was approved by the Council of Conservative Dentistry

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Table 1: Materials were utilized in the study

		Filler				
Material	*Specification*	*Type*	*Wt. (%)*	*Resin matrix*	*Manufacturer*	*Lot number*
Beautifil II LS	Giomer dental restorative material	Multifunctional glass fillers, S-PRG filler	83	Urethane diacrylate, Bis-MPEPP,(1) Bis-GMA,(2) TEGDMA(3)	SHOFU INC, Tokyo, Japan	052147
Estelite Sigma Quick	Nano-hybrid resin composite	Silica–zirconia	82	Bis-GMA(2) TEGDMA(3)	Tokuyama Dental, Tokyo, Japan	E758

(1)Bis-MPEPP, bisphenol a polyethoxy methacrylate; (2)Bis-GMA, bisphenolglycidyl methacrylate; (3)TEGDMA, triethylene-glycol dimethacrylate

Department, Faculty of Dentistry, October 6 University and the ethical issues were reviewed and revised by the Research Ethics Committee, Faculty of Dentistry, October 6 University on January 5, 2022 (Approval No. RECO6U/3-2022).

Sample Size Calculation

A power analysis was designed to have adequate power to apply a two-sided statistical test of the null hypothesis that there was no difference in color stability between tested groups. By adopting an alpha level of 0.05, a beta of 0.2, that is, power = 80% and an effect size (d) of 1.07 calculated based on the results of a previous study; the predicted sample size (*n*) was found to be a total of 30 samples (i.e., 15 samples per group). Sample size calculation was performed using G*Power version 3.1.9.7.[7]

Preparation of the Specimens

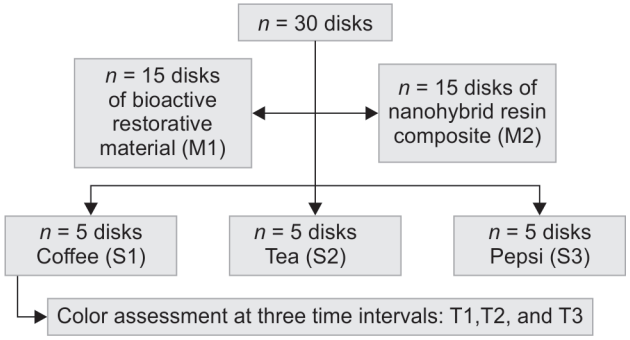
Using a Teflon split mold of a 2 mm thickness and 10 mm diameter, 30 disk-shaped specimens of resin composite were performed. The resin composite was added to the mold in one increment, slightly overfilling, and a thin glass slide was positioned below the mold. A Mylar strip was used to cover the resin composite surface, followed by another glass slide.[8] An axial weight of 500 gm for 60 seconds over the glass slide to flatten the surface and eliminate any excess. Photoactivation of the specimens was performed for 10 seconds according to the instructions provided by the manufacturer through the glass slide with intimate contact on either side by using Elipar™ DeepCure-L light-emitting diode with intensity 1,470 mW/cm^2 (3M™ ESPE, USA). The mold was disassembled, and the top surface of each specimen was examined using a magnifying lens (5.0 × Techne, Univet Loupes, Italy). Subsequently, a small indentation was made on the bottom part of every specimen using a small round bur. Super-Snap system (Shofu Inc., Japan) (Sof-Lex medium, fine, superfine) was utilized to finish and polish the specimens with a rotary low-speed handpiece with a maximum of 15,000 rpm (Strong 204 Saeshin Precision Co, Korea) with light hand pressure for 5 seconds for each disk by one operator. Disks had been changed after polishing each specimen. An incubator (Memmert GmbH, Germany) was utilized to keep the specimens in distilled water for 24 hours at 37°C to enable post-curing.[9]

Immersion Solutions Preparation

The storage solutions were coffee, tea, and Pepsi. Tea solution was performed by adding one prefabricated teabag instant 2 grams (Lipton—Yellow Label, Egypt) for 10 minutes into 150 mL of boiled distilled water. The coffee solution was done by combining 15 gms of coffee instant powder (Nescafe, Nestle, Egypt) with 200 mL boiled distilled water as recommended by the manufacturer; after stirring for 10 minutes, the coffee was filtered with filtering paper. Whereas Pepsi, kept at room temperature, was used directly without any preparation.[10]

Fig. 1: Storage of the specimens in the incubator

Flowchart 1: Grouping of the specimens



Immersion in Test Solutions

The samples were randomly allocated to two groups of 15 samples each:

- Group M1 – Beautifil LS II (Shofu, Japan).
- Group M2 – Estelite Sigma Quick (Tokuyama, Japan).

Each group was further randomly allocated into three subgroups S1 (Coffee), S2 (Tea), and S3 (Pepsi). To imitate the oral environment, each subgroup's samples (*n* = 5) were individually immersed in 30 mL of solution vials and placed in an incubator at 37°C for 10 min/day, then kept in distilled water for the remaining part of the day (Fig. 1, Flowchart 1). To avoid bacterial and yeast infections, the solutions were changed every 2 days. Each subgroup was evaluated at three different time intervals (T): 1 week (T1), 1 month (T2), and 3 months (T3). And 90 days of storage was equivalent to 12 months of beverage use.[11]

Color Analysis

Color measurement was carried out with VITA Easyshade® V (VITA Zahnfabrik, Germany). According to the manufacturer's

recommendations, two consecutive measurements were taken and reported for each specimen. To avoid any potential color absorption effect, the specimens were put over a white backdrop before color assessment[12] (Fig. 2). For each disk, four color measurements were made (baseline, after 1 week, 1 month, and 3 months) and the mean of the readings was calculated and used in data analysis. The specimen's color was expressed according to *Commission International de L'Eclainge* (CIELab) color system (L^*, a^*, and b^* values. The color difference ΔE was calculated from the mean ΔL^*, Δa^*, and Δb^* values for each specimen using the following formula:[7]

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

Statistical Method

Data management and statistical analysis were performed with Statistical Package for Social Science (SPSS) version 20. All quantitative data were explored for normality by using Shapiro–Wilk and Kolmogorov–Normality test and presented as means, standard deviation, mean difference, and percentage of changes values. Comparison between groups concerning the normality distributed numeric variables (color change) was performed using an independent *t*-test. One-way analysis of variance (ANOVA) test, followed by Tukey's *post hoc* test for multiple comparisons was used to compare different immersion solutions. Evaluation times were compared using repeated measures ANOVA.

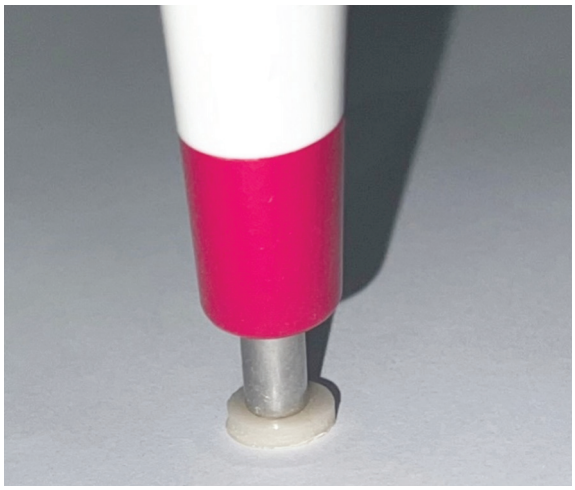


Fig. 2: Color measurement the specimens were placed over a white background

Results

The minimum, maximum, mean, and standard deviation of ΔE of both groups in all immersion solutions at all intervals are presented in Figure 3.

For the Giomer group, after T1, the samples immersed in coffee displayed the least mean value ΔE (2.27 ± 0.16) while the highest mean value of ΔE (6.45 ± 0.13) occurred at T3. For the specimens immersed in tea, the least mean value was recorded at T1 (2.45 ± 0.38) while the highest mean value was recorded at T3 (6.77 ± 0.09). For the specimens that were immersed in Pepsi, the least mean value was recorded at T1 (1.64 ± 0.19) while the highest mean value was recorded at T3 (5.54 ± 0.26).

For the Estelite Sigma Quick group, the specimens immersed in coffee showed the least mean value after T1 (1.34 ± 0.15) while the highest mean value of ΔE was recorded at T3 (4.22 ± 0.09). For the specimens immersed in tea, the least mean value was recorded at T1 (1.65 ± 0.16) while the highest mean value was recorded at T3 (5.44 ± 0.15). For the specimens immersed in Pepsi, the least mean value was recorded at T1 (0.95 ± 0.09) while the highest mean value was recorded at T3 (3.51 ± 0.26).

When comparing the effect of restorative material regardless immersion solution, we found that Giomer group showed a statistically significant higher value Estelite Sigma Quick group in all time intervals and three beverages. For the effect of immersion solution on the color change of restorative materials, we found that the highest mean value in both groups was shown in the Tea subgroup.

Discussion

As dental esthetics become increasingly important in both professional as well as personal lives, restorative materials must be able to effectively replicate the characteristics of dental tissues that had been lost.[5] The incredible innovation of novel restorative materials has successfully kept up with the huge need for esthetic

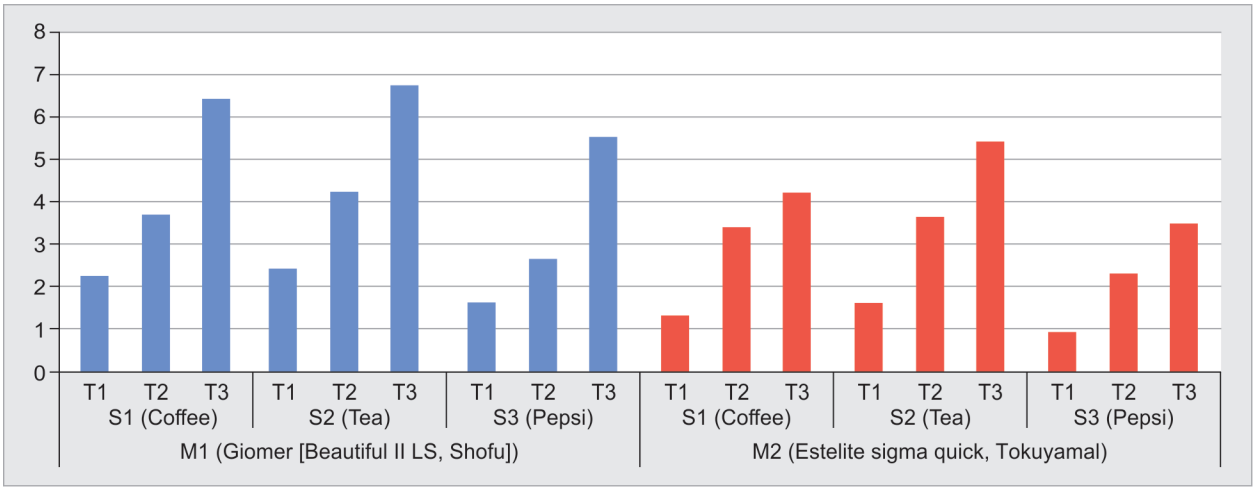


Fig. 3: Bar chart showing ΔE of both groups in the immersion solutions at all intervals

dentistry. Resin composites have become an essential part of modern esthetic restorative treatment. However, the success or failure of any esthetic restorative materials relies on the color stability and properties of the resin composite. The ongoing color stability of resin composites is crucial to the acceptability of restorations during their intraoral functional life, which is related to the frequent replacement of dental restorations. Color changes of resin composites are the result of regular exposure to both external and internal factors. Surface discoloration of resin restorations is a major factor affecting their longevity, thus emphasizing the importance of evaluating their color stability.[13] Therefore, the current study was conducted to estimate the color stability of Giomer restorative material vs nanohybrid resin composite after immersion in three commonly consumed beverages evaluated at three different time intervals.

Giomer is a uniquely designed category of esthetic restorative material. It is a viable combination of glass ionomer and resin composite. It is distinguished by its stable surface pre-reacted glass ionomer (S-PRG). This configuration contributes to the resin composite's ongoing esthetics, longevity, mechanical, and manipulating capabilities with fluoride release and replenishment properties by helping to protect the glass core from moisture. Recently, Beautifil II LS, a bioactive universal hybrid composite, was released.[14]

The application of nanotechnology in the field of resin composite materials, particularly nanofilled and nanohybrid resin composites, is a recent innovation. The most prevalent are nanohybrid resin composites, which increase mechanical, chemical, and optical properties by combining nanoparticles and submicron particles in the matrix.[15] Estelite Sigma Quick has a filler composition of 0.2 µm monodispersing spherical filler (Si-Zr). Particle diameters of 0.2 µm are well-known for producing the optimum combination of material properties and esthetics. The Estelite group contains supra-nanoparticles with particle sizes of 0.2 µm that are consistently distributed throughout the matrix.[16]

Color evaluation can be divided into two categories: visual evaluation and instrument evaluation. Instrumental evaluation has the potential to eliminate subjective errors in color assessments that can be observed visually. In the current study, a spectrophotometer was utilized to estimate the color assessment. To assess the colorimetric changes of dental materials objectively, the CIE *L*a*b** system is the most utilized method in the literature in the analysis of color stability of restorative materials which evaluates the perceptibility and acceptability of color in clinical and social life, according to the International Commission on Illumination.[17] The importance of the measurements should be postulated as only values equivalent to or more than 3.7 can be considered visually altered and may demand the alternative of restorations.[4] Staining of resin-based materials by beverages is mainly caused by the adsorption or absorption of colorants by the resin matrix. The rate of water sorption influences the resin's affinity for extrinsic stains. It was previously reported in the literature that the color stability of resin composites increases with decreasing inorganic particle sizes.[18] The recent investigation found that all investigated materials' colors changed over 90 days according to the results, this means that the time affects color stability of the esthetic restorative materials, and this was concurrent with many studies.[9,19,20] Therefore, the first and the second null hypotheses were rejected because all tested materials had color changes. Moreover, the staining media and the type of material both affected the color stability of all investigated materials. This was supported by other investigations.[9,20] It was found in the current study that the color stability of nanohybrid resin composite is better than Giomer restorative materials like the results reported by Faraoni et al.,[6] Rai and Naik[7] Huang et al.[20] and Ponnala et al.[13] Tanthanuch and Kukiattrakoon[21] and Gonulol et al.[22] stated that Giomer's hydrophilic character, high water sorption capacity, and the existence of a pre-reacted glass polyacid zone may explain the highest discoloration records, contrary to Adusumilli et al.[23] who stated that Giomer had the least color change due to higher TEGDMA concentration. According to the findings of this investigation, both materials became significantly stained after the immersion routine, with tea causing greater discoloration in Giomer than nanohybrid. This has been explained based on the nature of the filler particles present in Giomer as glass fillers have been reported to discolor more with tea. This is in agreement with the study previously stated in the literature by Gupta et al.[11] Many studies reported that tea was the most staining solution which is concurrent with findings from the current study. Altıparmak et al.[24] and Bahbishi et al.[19] reported that tea caused the most color change on all resin composites. Another study by Tekçe et al.[25] showed that tea caused a more significant color shift in resin-based materials than coffee. Moreover, Khade et al.[26] found that tea showed the maximum ability to stain resin composite samples, followed by black coffee, and Pepsi. The slight color change caused by submerging in Pepsi has been credited to its low pH. Its color ranged from pale yellow to dark brown. These results slightly varied with the results of Faris et al.[27] wherein they stated that it was the acidic pH of the beverage that affected the resin composite staining and Pepsi was responsible for maximum staining of resin composite, as it was the most acidic solution.[25] Sajini et al.[4] found that coffee staining intensity was found to be greater than tea. This may be due to the finding that the superficial color change was caused by tea exposure which can be easily removed by tooth brushing. Concerning coffee, color changes happen because of stains' superficial and deep absorption, making cleansing harder. However, only a few polarized stains from coffee infiltrate deeply into the restorative material. Tannin is a common constituent of coloring solutions, such as tea and coffee, which is highly chromogenic. Other factors affecting color change following immersion in coffee include the addition of sugar and its processing procedures such as filtering.[28] Therefore, the prepared immersion solutions were prepared without sugar. This was consistent with the study done by Sangeetha et al.[29] who stated that sugar might be responsible for staining restorative materials tea leaves have considerable amounts of flavonoids, which are responsible for taste as well as staining caused by tea. Caffeine and caffeic acid in the formulation of coffee are related to the color change of polymer materials.[30] Since tea is a highly popular drink, especially in Middle Eastern countries, dentists must inform the patients regarding the color change of the resin composite restorations due to exposure to tea. It has been recommended that patients should brush their teeth immediately after drinking tannin-containing solutions.[12]

Conclusion

Based on the current *in vitro* study's limitations, the following conclusions can be drawn; the color of bioactive restorative material is less stable if compared with nanohybrid resin composite. Regardless of the chemical formulation, storage in staining solutions reduces the color stability of esthetic restorative materials.

Tea is affecting the color stability of bioactive restorative material more than coffee and Pepsi.

Clinical Significance

As tea and coffee are popular beverages, particularly in Middle Eastern nations, dentists must advise patients about the color change of resin restorations. Patients are advised to brush their teeth immediately after consuming these beverages.

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