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Evaluation of color stability of injectable bulk-fill flowable composite and conventional composite when exposed to various beverages: In vitro study

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ORIGINAL STUDY

Evaluation of Color Stability of Injectable Bulk-fill Flowable Composite and Conventional Composite when Exposed to Various Beverages: An In-vitro Study

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Abstract

Purpose: This in-vitro study aims to assess the stability of color of injectable bulk-fill flowable composite and conventional composite materials, following immersion in various drinks, mimicking a half-year of clinical assistance. **Materials and methods:** Using a silicone mold, 33 disk specimens were created from each material. Group 1 ($n = 33$) was fabricated from injectable bulk-fill flowable composite and group 2 ($n = 33$) was fabricated from conventional composite. Specimens of each group were assigned to three subgroups ($n = 11$) according to the immersion solution (saliva, coffee, and Red Bull energy drink), incubated at 37 °C incubator, and color assessment was done at baseline and after immersion. Color changes (ΔE) were assessed using a spectrophotometer (VITA Easyshade). **Results:** There was no statistically significant difference recorded between injectable bulk-fill flowable composite and conventional composite groups after immersion in saliva and energy drinks. However, there was a statistically significant difference recorded between both groups after immersion in coffee. **Conclusions:** The tested resin composites that contain fluoride particles (Beautifil Flow plus F00 and Beautifil II LS) have a high probability of color change, so the composition of esthetic restorative materials plays an important role in their clinical performance. Patients who consume coffee and energy drinks must be aware of their negative effects on esthetic restorations containing fluoride particles. Injectable bulk-fill flowable composite can substitute conventional composite in anterior restorations that save time and obtain satisfactory esthetic.

Keywords: Coffee, Color stability, Energy drink, Resin composite

1. Introduction

In modern dentistry, esthetics has taken center stage. Patients today want very esthetic restorations, particularly when it comes to restoring their anterior teeth [1]. The surface quality of resin composite restorations, which is influenced by the restoration's shine and smoothness, is one of the key factors that makes them aesthetically pleasing. High levels of color stability, surface smoothness, marginal seal, and wear resistance are important characteristics that resin composite restorations should possess and preserve.

Because of the frequent pH changes brought on by food and drink consumption, restorations put in the oral environment may experience surface erosion and compromised surface integrity. This is especially true of resin composites. Solutions with an acidic pH may hydrolyze and degrade the polymer matrix. When certain elements of a photoinitiator system, such as tertiary aromatic or aliphatic amines, are exposed to light or heat, they may turn yellow or brown. The properties of the resin and its conversion rate, particularly the rate at which it absorbs water, also affect its susceptibility to external stains [2].

Injected resin that uses a transparent silicone index for accurate and predictable translation of a diagnostic wax-up into composite has become a popular choice for anterior teeth due to new clinical

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techniques that make the use of direct restorative materials easier, shorten the duration of treatment, and yield acceptable functional and esthetic outcomes. Flowable resins, characterized by low viscosity and good wetting properties, can penetrate all imperfections, and create layers with minimal thickness [3].

Nanoparticles were added to the composition of flowable resins as a consequence of research done to enhance their mechanical characteristics. Attributes related to material handling were unaffected by this modification. Comparing these resins to traditional resin composites, research has indicated that while they have superior polishing, they have poor wear resistance and color stability [4].

The surface or subsurface layers of resin restorations in the oral cavity may become discolored due to superficial deterioration or the penetration and sorption of staining solution in the superficial layer of composite resins [5].

Energy drinks are carbonated beverages that include vitamins and other substances to boost energy levels temporarily. These beverages are designed to boost alertness and physical resistance. They also improve focus, speed up metabolism, and aid in the body's removal of toxic chemicals. Candidates, college students, and office workers love energy drinks and coffee because they boost concentration and reduce fatigue [6].

Compared with the extensively studied conventional composite materials, there is not enough information in the literature about how actual daily use of these drinks affects the color stability of injectable bulk-fill flowable composites. Thus, it was concluded that the current study's investigation of the impact of immersion with different staining beverages of coffee, artificial saliva, and Red Bull on the color stability of two types of resin composites, injectable bulk-fill flowable composite and conventional composite, simulating 6 months of clinical service, was beneficial [7]. Therefore, the purpose of this study is to look into how several typical drinks that patients drink affect those composites. This research study hypothesizes that the color stability of composite is not impacted by different color mediums.

Our study was performed to assess the stability of color of injectable bulk-fill flowable composite and conventional composite materials, following immersion in various drinks, mimicking a half-year of clinical assistance.

2. Materials and methods

First, the study had been approved by the Research Ethics Committee, Faculty of Oral and Dental Medicine, Ahram Canadian University, Research number: IRB00012891#90. The current study used two distinct composite materials; a list of the resin composites used in this study is given in Table 1.

2.1. Sample size calculation

The estimation of the sample size was based on other research found in the literature [2]. The study found that the lowest acceptable sample size for each group was 11, with group 1's mean ± SD being 11.27 ± 2.59 and group 2's mean ± SD being 7.45 ± 3.58. The effect size was 1.25 when the power was 80 % and the type I error probability was 0.05. To conduct an independent *t*-test, G. Power 3.1.9.7 was used.

2.2. Sample preparation and grouping

Using a silicone mold, 33 disk specimens (10 mm diameter and 2 mm thickness) were created from every material, where group 1 ($n = 33$) was fabricated from injectable bulk-fill flowable composite and group 2 ($n = 33$) was fabricated using the conventional composite. Specimens of each group were assigned to three subgroups according to the immersion solution (saliva, coffee, and Red Bull energy

Table 1. Resin composites used with their composition.

Material (shade)	Manufacturer	Type	Matrix composition	Filler (wt%) vol%
Beautifil Flow plus F00 (A2)	Shofu Inc., Kyoto, Japan	High-viscosity flowable resin composite	Bis-GMA (15 wt%)/TEGDMA (13 wt%)	S-PRG filler based on fluoroboroaluminosilicate glass 67.3%
Beautifil II LS (A2)	Shofu Inc., Kyoto, Japan	Nanohybrid low-shrinkage giomer composite	Bis-GMA (7.5 wt%)/TEGDMA (5 wt%)	S-PRG based on fluoroboroaluminosilicate glass 83.3%

Composition determined by the manufacturer.
AFM, addition–fragmentation monomer; AUDMA, aromatic urethane dimethacrylate; BisEMA, ethoxylated bisphenol-A-dimethacrylate; Bis-GMA, bisphenol-A-glycidyl dimethacrylate; Bis-MPEPP, bisphenol A polyethoxy methacrylate; DDDMA, 12-dodecanol dimethacrylate; DUDMA, diurethane dimethacrylate; EBPADMA, ethoxylated bisphenol A dimethacrylate; UDMA, urethane dimethacrylate; wt%, weight%.

drink), incubated at 37 °C incubator. During the sample preparation, a 1 mm thick glass slab with light pressure and a Mylar strip was placed on the silicone mold (Fig. 1). The pressure had two functions: it cleared the mold of any excess composite material. It guaranteed that the disk thickness and distance between the disk and the light curing tip were standard. Each sample was light-cured through the Mylar strip and the glass slab for 20 s by a light-emitting diode curing unit (Guilin Woodpecker Medical Instrument Co. Ltd, Guilin, Guangxi, China), at a light intensity of 1000 mW/cm^2 from the upper and lower surfaces. Using a spectroradiometer (Demetron Research Corp., Demetron/Kerr, Danbury, CT, USA) the light-emitting diode curing unit's light intensity was measured. Subsequently, using 3 M Sof-Lex Diamond Polishing disks, the disks were polished using the same amount of strokes for each disk [8].

2.3. Color assessment

Before immersion, the tooth shade of each specimen was determined by color measurements (L*, a*, and b* values) by a mobile spectrophotometer (VITA Easyshade, Vident, Brea, California, USA). The contact probe's tip was positioned 90° over the surface. Thirty-three samples of every material were split into three subgroups randomly according to the staining beverage used to measure the change in color in the three drinks. Subgroup 1: artificial saliva (0.4 g NaCl, 0.4 g KCl, 0.6 g $CaCl_2$, 0.6 g NaH_2PO_4, 4 g urea, 4 g mucin, 0.0016 g Na_2S, 0.0016 g $Mg_2P_2O_7$ + 1 l distilled water, pH≈7) (8), subgroup 2: coffee (Nescafe Classic, Nestle, Morocco, 3.6 g of coffee powder was diffused in 300 ml of boiling distilled water, pH≈5), subgroup 3: energy drink (Red Bull GmbH), carbonated water, sucrose, glucose, acidifier citric acid, taurine (0.4 %), acidity regulators (odium bicarbonate, magnesium carbonate), flavors (natural and artificial), colors (caramel, riboflavin), caffeine (0.03 %), vitamins (niacin, pantothenic acid, B6, B12, pH≈3.3). Each fresh immersion solution's pH was assessed every day using a pH meter (Orion Dual Star, pH/ISE meter; Thermo Scientific Inc., Waltham, Massachusetts, USA). [9].

Fig. 1. Glass slab and Mylar strip were placed on the silicone mold.

The staining solution was exposed to both sides of the composite specimens when they were put into the containers. Throughout the investigation, the specimens were kept in tight containers to prevent the staining solutions from drying out. To prevent bacterial or fungal contamination, the staining beverages were replaced every day [10]. The samples were maintained at 37 °C in an incubator for 6 days [7], except for periods when beverage changes and color assessment were conducted:

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

Following immersion, each specimen was taken out and given a 5-min gentle rinse under running distilled water before being allowed to dry. Next, the measurements for the second color were carried out as the color assessment was done at baseline and then after 6 days of immersion. The color difference (ΔE lab) was calculated by the subsequent equation, which considered variations in the noted coordinate parameters before and after immersion [10]. The color range between black and white was represented by L*, the place of color on the green and red axis by a*, and the place of color on the yellow and blue axis by b* according to prior studies (10). Up to ΔE = 3.3, a discernible color shift with ΔE more than 1 was considered acceptable.

2.4. Statistical analysis

Kolmogorov–Smirnov and Shapiro–Wilk tests were used to investigate the normality of numerical data. The color change data displayed a parametric, or normal, distribution. For all the groups, the mean and SD were calculated. However, independent sample *t*-test was used for comparing two groups in unrelated specimens. One-way analysis of variance was used for comparing more than two groups in related specimens. A threshold of *P* value less than 0.05 was determined to be significant. IBM SPSS Statistics (1 New Orchard Road Armonk, New York 10504-1722. United States), version 22 for Windows was used for statistical analysis.

3. Results

Following immersion in various solutions, the groups' overall color shift (ΔE) was recorded: Table 2

Table 2. Mean, SD, and P value of overall color change (ΔE) recorded for groups after immersion in different solutions.

	Overall color change (ΔE) within groups				*P* value
	Injectable bulk-fill flowable composite		Conventional composite		
	Mean	SD	Mean	SD	
Saliva	1.84Ca	0.35	1.54Ca	0.42	0.32 ns
Coffee	12.11Ab	0.57	18.30Aa	2.4	0.001*
Energy drink	7.72Ba	0.87	9.33Ba	1.65	0.09 ns
P value	<0.001*		<0.001*		

A statistically significant difference within the same row was shown by small letters, while a statistically significant difference within the same column was indicated by superscripts with different capital letters. Ns: nonsignificant ($P > 0.05$), *significant ($P \leq 0.05$).

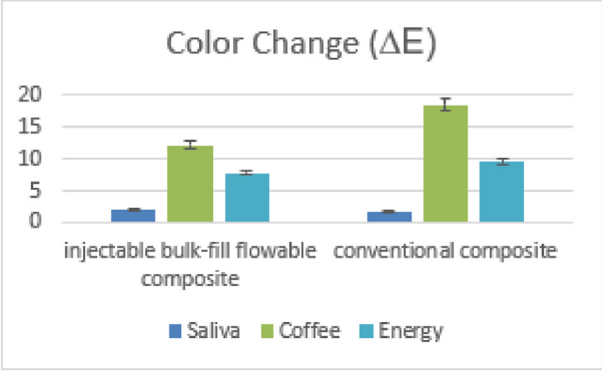

Fig. 2. Bar charts representing overall color change within each group after immersion in different solutions.

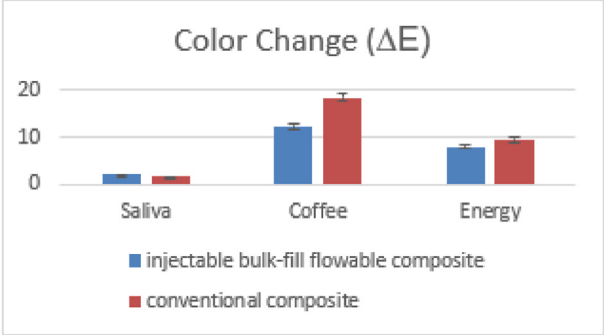

Fig. 3. Bar charts representing overall color change between groups after immersion in different solutions.

and Fig. 2 listed the ΔE means and SDs for the injectable bulk-fill flowable composite and conventional composite groups following immersion in various solutions.

After immersing the injectable bulk-fill flowable composite group in various solutions, the overall color change (ΔE) differed in a statistically significant manner with a *P* value of less than 0.001. The coffee immersion yielded the greatest mean value (12.11) followed by energy drink (7.72), while the lowest mean was noted after immersion in saliva (1.84).

Regarding the conventional composite group, there was a statistically significant difference in overall color change (ΔE) recorded after immersion in different solutions where *P* value less than 0.001. The highest mean value was recorded after immersion in coffee (18.3) followed by energy drink (9.33), while the lowest mean was recorded after immersion in saliva (1.54).

Table 2 and Fig. 3 list (ΔE) mean values that were recorded between injectable bulk-fill flowable composite and conventional composite following immersion in various solutions. Following immersion in saliva and energy drink, neither group showed any statistically significant differences where the *P* values recorded being 0.32 and 0.09, respectively, but following immersion in coffee, a statistically significant difference between the two groups was noted ($P = 0.001$), with the conventional composite recording the greatest mean value (18.3).

4. Discussion

Esthetic, functional, form, and phonetic considerations make restorations for anterior teeth especially difficult. The most popular restorative material for cosmetic restorations is a composite material based on resin.

First, the surface properties and color stability of resin composite restorations are what primarily dictate their success. However, discoloration is still a major problem, especially if the restorations are left in the mouth for a long time. This color change not only affects the restoration's color matching but also makes the patient unhappy, requiring a further expensive repair [11].

Consumption of staining beverages is one of the common causes of color alteration. Discoloration can occur when colored components from frequently consumed beverages, such as tea, coffee, cola, and energy drinks, accumulate onto the teeth's surface and the composite resin restoration. Due to the decreased surface hardness and smoothness of the resin restorations such beverages, may cause more discoloration [12].

Thus, it is crucial to preserve the material's intrinsic qualities, such as stability of color to maintain an esthetic outcome. Therefore, this study aimed to evaluate the color stability of two resin composite compositions [13]. The average person who drinks coffee takes 15 min to finish a cup, and they typically drink 3.2 cups a day, according to the coffee maker. Thus, a 24-h storage period is equivalent to around 1 month's worth of coffee consumption. For 6 days, specimens were submerged, mimicking the consumption of 6 months [7].

A spectrophotometer was used to measure the shade changes both before and after the sample had been immersed in the solution of staining to determine the CIEL*a*b* parameters. This study used the well-known CIE Lab system, which is one of the most widely used color measurement tools in the dental field, and produced accurate results for parameters of color [14].

Variations of color of dental materials or teeth before and after a procedure were displayed by the ΔE value. Literature states that values with an ΔE less than 1 were considered insignificant to the human eye. However, values of ΔE more than 3.3 were regarded as noticeable by nonskilled individuals and are, therefore, not clinically acceptable. Values of $1 < \Delta E < 3.3$ were deemed noticeable by skilled operators but clinically acceptable. Consequently, color changes were deemed clinically unacceptable if they exceeded a value of $\Delta E = 3.3$ [13].

The hybrid restorative material Beautifil is referred to as a giomer. Within a resin matrix, it contains pre-reacted glass ionomer fillers. Giomer composites' properties related to water sorption allow them to release fluoride ions. Osmotic pressure may be generated by the giomer structure's pre-reacted zones, which could enhance the material's water sorption. Water-soluble colorants can discolor the composite material due to water sorption [15].

The release of nonfluoride ions from the S-PRG filler has several advantages, including the release and recharge of fluoride, the development of an acid-resistant layer, antiplaque action, remineralization of dentin, and the ability to buffer acid and the decrease in acid production by acid-producing bacteria. Regarding color change of the two types of composites, there was no statistical significance in artificial saliva and the energy drink, while there was statistical significance in the coffee group.

In both artificial saliva and energy drink groups, when compared with their traditional alternatives, the Beautifil 2 and Beautifil I giomers' particles' lower staining susceptibility may be partially accounted for their comparatively higher TEGDMA content. These findings concur with those of Vyas and colleagues, who reported a statistically significant difference in color between the two kinds of composites: Beautifil II and injectable Beautifil after immersion in tea, due to the chemical structure of both composites [13].

Also, these results agree with Faraoni and colleagues, in which Beautifil II had a significant color change in different drinks, and they assumed that e these results were because of the acidic immersion solution. This might have deteriorated the resin's surface and affected how light was reflected [16]. Perhaps its composition, which is different from the resin matrix composition, particle size, and conversion following polymerization, is the cause. The resin matrix, which maintains color stability, has an impact on higher staining. It can absorb more or less water (and other substances) according to its chemical composition, which causes discoloration.

Triethylene glycol dimethacrylate (TEGDMA), which has high resistance to stains than bisphenol A glycidyl ether dimethacrylate (Bis-GMA) is an additional possibility and may improve hydrophilicity when compared with urethane dimethacrylate (UDMA). Because Beautifil II contains two resin monomers (Bis-GMA and TEGDMA), its simplicity can also be used to explain its unstable behavior [17].

Also, the same results were shown by Gonulol and colleagues who compared the color stability of giomers and nanohybrid Filtek Z550 composite following water immersion, and they came to a conclusion that the giomer (Beautifil) group's discoloration values were significantly greater to a degree, where it would have a detrimental effect on their artistic ability. Giomers are fluoride-releasing compounds, hence this observation has been attributed to the kind of material. This could have led to roughness and voids in the matrix, and this could be a factor in giomer restorative materials' decreased color stability [18].

Meanwhile, these results disagree with Ozkanoglu and Akin, who found that throughout a 6-week staining period, resin composites immersed in coffee showed more staining than those in cola or tea. Nevertheless, no notable distinction was found between the composite materials [19].

In our study, there was a significant change in color in both types of composites stained with coffee, and it showed the greatest color alteration that is statistically significant followed by the energy drink, and the lowest significant was with artificial saliva.

Regarding color change after immersion in coffee, these results agree with Sajini *et al.* [20] in which

coffee resulted in the highest color change, and also AlSheikh found a significant change in color of composite after immersion in coffee, the existence of yellow staining molecules with a strong affinity for polymer molecules may have contributed to the coffee's increased staining capability [21].

It is possible that the coffee's temperature accelerated the degree of intrinsic staining by acting as an aging agent. Because of its effect on the photo-initiator, temperature alone can also influence a composite material's discoloration [22].

Regarding the change in color of composite disks following immersion in energy drink, these results disagree with the outcomes attained by Al-Dharrab [23]. It claimed that there was a statistically insignificant color change for composite resins immersed in Red Bull.

In agreement with Hamadamin and Saeed [6] who found a significant color alteration of the composite after immersion in Red Bull drinks and likewise agreeing with Tsikkini *et al.* [18], who stated a significant color change after immersion in Red Bull. This change was attributed to the acidic pH, which may worsen dental materials' resistance to wear and accelerate polymer degradation and, therefore, leads to color change. Red Bull contains citric acid and is acidic in nature; the pH value of Red Bull is 3.54. Although this low pH leads to color change that low pH has an impact on the composite resin's surface integrity, it results in less discoloration than coffee.

Regarding color change upon immersion in artificial saliva, this result agrees with Faraoni and colleagues, who found a statistically significant change in the color of composite disks following immersion in artificial saliva and stated that this might have occurred because of components of artificial salivas and resin matrix water sorption [16], and in agreement with Ahmadizenouz *et al.* [24], who mentioned that water sorption of the matrix can cause swelling and plasticization of the polymer as well as the creation of interfacial spaces between the resin matrix and filler that permit stain penetration and discoloration, which could be the cause of the color shift.

One of the study's shortcomings is that the impact of the materials' surface roughness on color variations was not examined. Moreover, samples were not brushed when solutions were changed to mimic patients' consumption, which might have changed the materials' susceptibility to staining. Future studies ought to examine the way temperature stresses, brushing, and surface roughness affect the stability of the color of restorative materials. Consequently, more in-vitro, ex-vivo, and in-vivo research is required to fully comprehend how hybrid composite resins behave in the oral cavity when exposed to solutions and beverages that are intended for commercial use.

4.1. Conclusions

Within the limitation of the present study, it was concluded that the tested resin composites that contain fluoride particles (Beautifil Flow plus F00 and Beautifil II LS) have a high probability of color change, so the composition of esthetic restorative materials plays an important role in their clinical performance. Patients who consume coffee and energy drinks must be aware of their negative effects on esthetic restorations containing fluoride particles. Finally, injectable bulk-fill flowable composite can substitute conventional composite in anterior restorations that save time and obtain satisfactory esthetic.

4.2. Recommendations

Consequently, more in-vitro, ex-vivo, and in-vivo research is required to fully comprehend how hybrid composite resins behave in the oral cavity when exposed to solutions and beverages that are intended for commercial use.

Ethical information

The study had been approved by the Research Ethics Committee, Faculty of Oral and Dental Medicine, Ahram Canadian University, Research number: IRB00012891#90.

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Conflicts of interest

There are no conflicts of interest.

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