

# Color Stability in A Giomer, A Conventional Glass Ionomer and A Resin-Modified Glass Ionomer Exposed to Different Pigment Beverages: An *In vitro* Comparative Study

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## Abstract

**Aim:** Discoloration in ionomeric materials occurs by absorption of substances, so color stability is important because these materials are of choice to restore class V. The purpose of the current study was to evaluate the color stability of a giomer, a conventional glass ionomer and a resin-modified glass ionomer exposed to different beverages with different immersion times. **Materials and Methods:** This *in vitro* experimental and longitudinal study had 135 discs were sampled in total (2 mm thick × 8 mm in diameter) distributed in three equal groups ( $n = 45$ ): Beautifil II, Vitremer, and Ketac Universal. Each group was divided into three equal subgroups ( $n = 15$  each group) and immersed in three different staining solutions: coffee, Coca-Cola®, and red wine. Color change was recorded with the Vita Easyshade® spectrophotometer after 1 h, 24 h, and 1 week of immersion. Measures of central tendency and dispersion were calculated. Kruskal–Wallis and Friedman nonparametric  $H$  tests were used to compare independent measures. The Bonferroni post hoc was used considering a significance level of  $P < 0.05$ . **Results:** Beautifil II ( $P < 0.05$ ) and Ketac Universal ( $P < 0.05$ ) showed significant differences with respect to color variation ( $\Delta E$ ) when comparing exposure to Coca-Cola® versus exposure to coffee and red wine for 1 h, 24 h, and 1 week. Vitremer showed no significant differences when exposed to Coca-Cola®, coffee, and red wine for 1 h, 24 h, and 1 week ( $P = 0.607$ ,  $P = 0.276$ , and  $P = 0.134$ , sequentially). All three restorative materials, after 1 hour immersed in Coca-Cola®, showed  $\Delta E < 3.3$  and Beautifil II obtained  $\Delta E = 3.12$  after 24 h immersed in the same beverage. **Conclusion:** Coffee and red wine significantly varied the color of Beautifil II and Ketac Universal over time. Beautifil II and Ketac Universal showed significantly more pigmentation with red wine and less with Coca-Cola® at 1 week immersion. Vitremer showed no significant differences when exposed to Coca-Cola®, coffee, and red wine at all times tested. There were clinically acceptable variations for all three restorative materials immersed in Coca-Cola for 1 h. This clinical threshold was only maintained for the Beautifil II giomer up to 24 h of immersion in the same beverage.

**Keywords:** Color variation, comparative study, dental materials, dentistry, giomer, ionomer

**Received:** 25-04-2023, **Revised:** 05-07-2023, **Accepted:** 05-07-2023, **Published:** 31-08-2023.

## INTRODUCTION

Glass ionomer cement (GIC) was introduced in dentistry as a biocompatible translucent filling material that may chemically attach to tooth structure. It exhibits high fluoride release and its chemical bond to tooth structure makes it a material of choice for restoration, luting, or base.<sup>[1-3]</sup>

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**How to cite this article:** Alacote-Mauricio B, Gihuaña-Aguilar C, Castro-Ramirez L, Cervantes-Ganoza L, Ladera-Castañeda M, Dapello-Zevallos G, *et al.* Color stability in a giomer, a conventional glass ionomer and a resin-modified glass ionomer exposed to different pigment beverages: An *in vitro* comparative study. J Int Oral Health 2023;15:357-66.

Access this article online

Quick Response Code:



Website:  
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DOI:  
10.4103/jioh.jioh\_93\_23

Despite all their benefits, conventional glass ionomers also exhibit a number of drawbacks such as dehydration, initial sensitivity to moisture, a delayed setting response time, and a rough surface texture. All these factors can negatively affect the mechanical properties of restorations and lead to clinical failures.<sup>[4,5]</sup> These low mechanical properties mean that they are not the most frequent choice in clinical practice.<sup>[6]</sup> Some studies mention that these ionomers show discoloration by adsorption or absorption of stains. This may be influenced by the porosity of the glass particles. Also, the potential color change may be due to physicochemical reactions that occur in this restorative material.<sup>[7,8]</sup> To address all of these drawbacks, various ionomer material compositions have been created to improve material handling, expand working times, and improve esthetics.<sup>[9]</sup> Such formulations include high-viscosity glass ionomers, polyacid-modified composite resins, giomers, and resin-modified glass ionomer cements.<sup>[4]</sup> Incorporating nano-sized filler particles into glass ionomer-based materials can improve mechanical qualities, wear resistance, color stability, and resistance to biomechanical deterioration.<sup>[10]</sup>

Color stability is an important property in restoration materials that can be due to extrinsic (exogenous) or intrinsic (endogenous) factors. The extrinsic factor is the one that affects color stability most significantly. Such factors are related to the absorption of dyes by consuming certain beverages as coffee, tea, alcohol, and soft drinks.<sup>[8]</sup> This color stability in restorative materials is required to assess the treatment's success or failure. Because of the presence of bacteria, saliva, and frequent consumption of foods and beverages in the oral cavity, the esthetics of these glass ionomers are damaged when exposed to this environment. It is a challenge for the dentist to deal with these factors and perform optimal and satisfactory treatments for the patient.<sup>[11]</sup> Taking into account that ionomers have become a material of choice to restore class V dental caries due to their good properties such as the ability to bond to enamel and dentin, biocompatibility with dental tissue and the release of fluoride ions.<sup>[12,13]</sup> Because of the current demand for the use of ionomeric restorative materials and giomer, and concomitant with this the trend of increasing consumption of acidic beverages, further studies are needed to evaluate the effects of acidic beverages on these types of restorative materials. These studies should be carried out by monitoring the temperature of the beverages over time for standardized color monitoring.

Given the foregoing, the current study sought to assess the color stability of a conventional glass ionomer, a giomer, and a resin-modified glass ionomer exposed to different beverages with different immersion times. The null hypothesis was that there are no statistically significant differences in the color stability of ionomer or giomer-based materials over time.

## MATERIALS AND METHODS

### Study design

This *in vitro* and experimental longitudinal research was conducted from February 2022 to July 2022 at the Universidad Privada San Juan Bautista and in a certified high-tech laboratory (ISO/IEC: 17025) in Lima, Peru, with approval Letter No. 282-2022-CIEI-UPSJB and taking into account the checklist for reporting *in vitro* studies.<sup>[14]</sup>

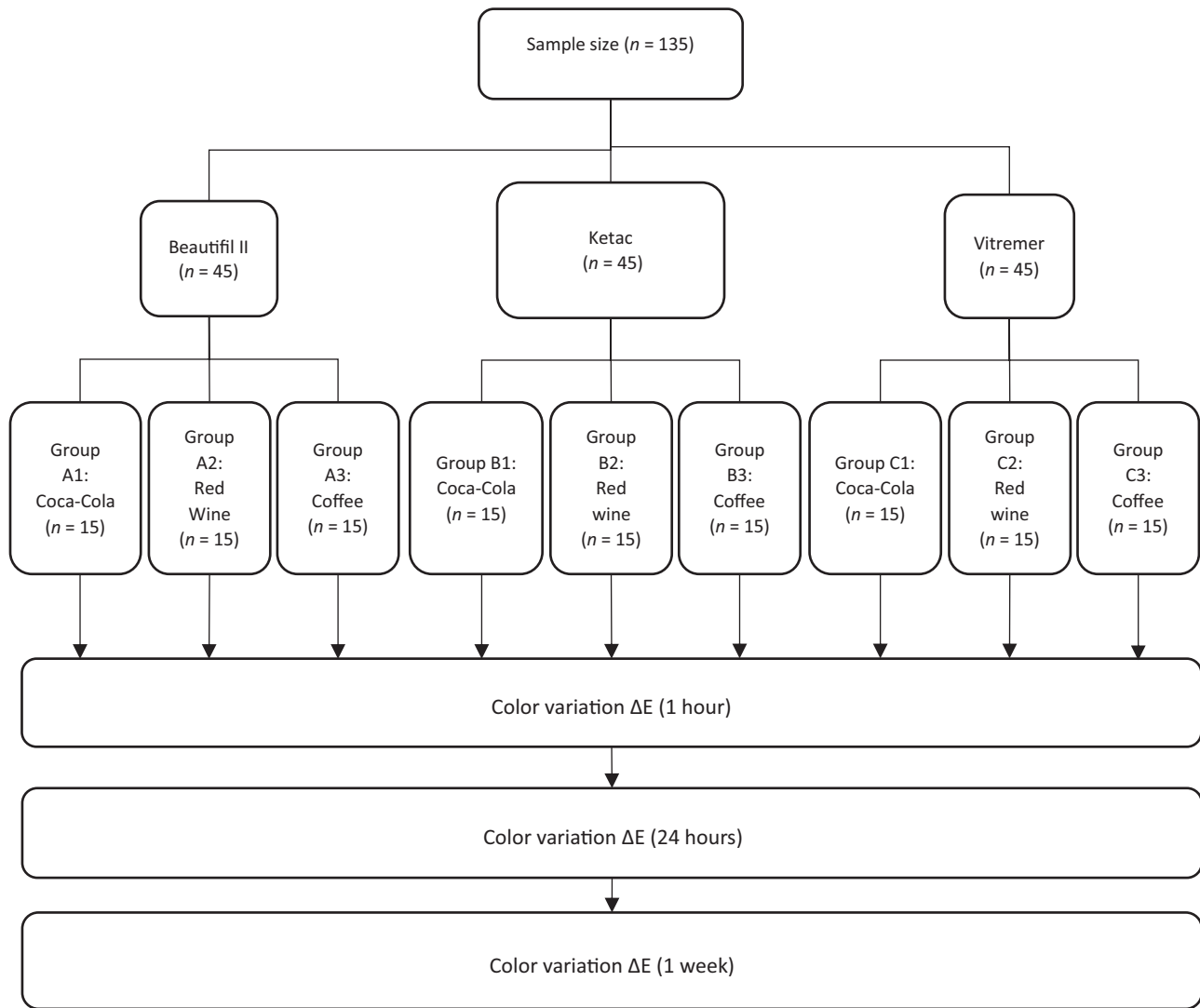
### Sample calculation and selection

A total of 135 ionomer and giomer discs were prepared and standardized and evenly divided into three groups of 45 disc, then redivided in a simple random fashion without replacement based on their exposure to beverages: Coca-Cola® ( $n = 15$ ), red wine ( $n = 15$ ), and coffee ( $n = 15$ ) [Figure 1]. The overall sample size ( $n = 135$ ) was derived using data from a prior study with five samples per group, taking into account a significance level ( $\alpha$ ) = 0.05, a statistical power ( $1 - \beta$ ) = 0.80, and an effect size 0.291, with nine subgroups and three related measures.

### Sample characteristics and preparation

Three restorative materials were used [Table 1]: Beautifil II (Shofu Inc., Kyoto, Japan), Vitremer (3M/ESPE, St. Paul, Minnesota) and Ketac Universal (3M/ESPE). Forty five discs of each restorative material type were made for a total of 135 units of analysis. All samples measured 8 mm in diameter  $\times$  2 mm in thickness<sup>[6,15,16]</sup> and were made by a single operator.

A standardized metal matrix was used to manufacture the disc. The material was placed in the mold, celluloid tape was applied to both sides and the glass plate was gently pressed to eliminate excess material.<sup>[4,6]</sup> The samples prepared with Beautifil II and Vitremer were light cured with an LED lamp (Valo®, Ultradent South Jordan, Utah) at 1000 mW/cm<sup>2</sup> for 20 s. The intensity was checked with a radiometer (Woodpecker® LM-1, Woodpecker, Guilin, Guangxi, China). Samples using Ketac Universal (3M/ESPE) were given time to self-cure according instructions provided by the manufacturer. The materials were treated under regulated conditions of temperature ( $23^\circ \pm 1^\circ \text{C}$ ) and relative humidity ( $50\% \pm 5\%$ ). The powder was mixed with the liquid for Vitremer and Ketac Universal on a wax paper disc with a plastic spatula. The powder/liquid ratios used and the handling were carried out according to the manufacturer's instructions. Each disc was polished for 20 s by the same operator according to the manufacturer's instructions. An electric motor (EM-E6, W&H, Bürmoos, Austria), an angle piece (NSK, Tokyo, Japan), and a four-stage disc system (Sof-Lex, 3M/ESPE) at 15,000 rpm were used. The disc surface was moistened between uses to prevent overheating and surface deterioration. After that, to eliminate surface residues, the discs were washed and dried.



**Figure 1:** Random distribution of groups according to sample size

**Table 1: Technical profile of products used**

Product	Type	Composition	Ratio recommended	Manufacturer	Lot
Beautifil II	Giomer	Bis-GMA, TEGDMA, S-PRG filler, multifunctional glass filler	–	Shofu Inc., Kyoto, Japan	062126
Vitremer	Resin-Modified Glass ionomer Cement	Powder: fluoroaminosilicate glass, potassium persulfate, ascorbic acid Liquid: aqueous solution of a polycarboxylic acid modified with pendant methacrylate groups, water, HEMA, photoinitiators	2.5:1	3M, ESPE, St. Paul, MN, USA	NE38788
Ketac™ Universal	Glass ionomer	Powder: oxide glass Liquid: copolymer of acrylic acid—maleic acid, tartaric acid, benzoic acid, water	3.2:1	3M, ESPE, St. Paul, MN, USA	7723861
Sof-Lex system	Finishing polishing system	Aluminum oxide abrasive discs	SL coarse: 60 μm SL medium: 29 μm SL fine: 14 μm SL superfine: 5 μm	3M, ESPE, St. Paul, MN, USA	NE04288 NE04500 NC80025 NC93140

The samples were checked for voids, cracks and irregularities. This procedure was repeated until a sufficient number of samples were acquired. The

Vitremer-made discs were coated with Finishing Gloss (included in the manufacturer's packaging) after polishing with a disposable brush and then light-cured for 30s.

**Table 2: Immersion media used**

Product	pH	Manufacturer
Coke	2.4	The Coca-Cola Company, Atlanta, GA, USA
Red wine	3.82	Santiago Queirolo, Viñas Queirolo, Cañete, Ica, Peru
Coffee	5.45	Nescafé®, Nestlé, Lima, Peru

All discs were placed in an airtight container filled with distilled water and kept at 37°C<sup>[13-15]</sup> for 24h to prevent discoloration due to external factors, prior to the first color evaluation.

### Staining protocol

Fifteen discs of each restorative material were immersed to each of the solutions [Table 2]: 5 mL of Coca-Cola®, 5 mL of red wine, and 5 mL of coffee. These beverages were replaced daily and their temperature was standardized to 37°C each time they were replaced.<sup>[17,18]</sup> Coca cola and red wine were used directly without any preparation and coffee was prepared 25g in 250 mL of water.<sup>[15]</sup> The containers were covered during the experiment to avoid evaporation of the solutions. The immersion times used were 1 h, 24 h, and 1 week, as the methodology used by Pani *et al.*<sup>[2]</sup>

### Color change measurement

Initial color values were assessed using a spectrophotometer (Vita Easyshade®, V Zahnfabrik, Bad Säckingen, Germany) using ISO/Commission Internationale d'Eclairage (CIE) 11664-6:2022 CIELAB scales<sup>[19]</sup> before starting the immersion protocol. Individual color parameters ( $L^*$ ,  $a^*$ ,  $b^*$ ) representing luminance values, red/green values, and blue/green values, respectively, were measured. Each sample was subjected to two measurements, and the instrument was calibrated in accordance with the manufacturer's instructions before each test. To guarantee precise measurements, the probe tip was positioned vertically and adjusted to the sample surface. The measurements were performed against a black box with standardized position, angle, and ambient illumination. After soaking in the beverages for 1 h, 24 h, and 1 week,<sup>[2]</sup> the discs were cleaned with distilled water and dried with absorbent paper for color measurement. The same operator conducted all measurements in the same setting. The color change was computed using the CIEDE2000 color system and the formula below:

$$\Delta E_{00} = \left[ \left( \frac{\Delta L}{K_L S_L} \right)^2 + \left( \frac{\Delta C}{K_C S_C} \right)^2 + \left( \frac{\Delta H}{K_H S_H} \right)^2 \right]^{1/2} + R_T \left( \frac{\Delta C}{K_C S_C} \right) \left( \frac{\Delta H}{K_H S_H} \right)$$

The brightness, chroma, and color changes between the original and later measurements were represented by  $\Delta L$ ,

$\Delta C$ , and  $\Delta H$ , respectively.  $S_L$ ,  $S_C$ , and  $S_H$  are weighting functions included in the formula to remove observed discrepancies in luminance, chroma and hue, in the CIE  $L^*a^*b^*$  system. For RT, colors within the same color density radius are assumed to have a value of 0 ( $\Delta C = 0$ ).  $K_L$ ,  $K_C$ , and  $K_H$  are parametric factors calculated for luminance, chroma, and hue. They are incorporated into the formula to account for inaccuracies brought on by experimental factors such as the material's surface and the background used in the measurement.<sup>[6]</sup> Everything was performed according to the instructions of ISO/CIE11664-6:2020.

### Statistical analysis

The obtained data were analyzed into SPSS (IBM Statistical Package for Social Sciences, New York, New York) version 28.0 for statistical analysis. Means, medians, standard deviations, and interquartile ranges were calculated for descriptive analyses. To test the hypotheses, the Shapiro Wilk, and Levene's tests are employed to determine whether the data are normal and homogeneous. Considering the findings, the non-parametric Kruskal–Wallis test was considered to be appropriate for comparing more than two independent measurements and the Friedman test for comparing more than two related measurement. In addition, Dunnet post hoc analysis with Bonferroni correction was used. All comparisons were considered at a significance level of  $P < 0.05$ .

### RESULTS

Significant differences in color variation ( $\Delta E$ ) were observed when comparing exposure to Coca-Cola® versus exposure to coffee and red wine for both Beautifil II ( $P = 0.001$  and  $P < 0.001$ , sequentially) and Ketac Universal ( $P = 0.001$  and  $P = 0.024$ , sequentially). At 24h of exposure, significant differences were also identified when comparing exposure to Coca-Cola® with exposure to coffee and red wine for both Beautifil II ( $P = 0.001$  and  $P < 0.001$  sequentially) and Ketac Universal ( $P = 0.004$  and  $P = 0.045$ , sequentially). At 1 week of exposure to Coca-Cola®, differences were observed for both Ketac Universal ( $P = 0.003$  and  $P = 0.033$ , sequentially) and Beautifil II ( $P = 0.005$  and  $P < 0.001$ , sequentially) compared to coffee and red wine. Vitremer showed no significant differences when exposed to Coca-Cola®, coffee and red wine for 1 h, 24 h, and 1 week ( $P = 0.607$ ,  $P = 0.276$ , and  $P = 0.134$ , sequentially) [Table 3].

After 1h of immersion in Coca-Cola®, significant differences could be found in the color variation ( $\Delta E$ ) between Beautifil II and Vitremer ( $P = 0.002$ ). At 24h immersion in the same beverage, significant differences were observed between Vitremer with Beautifil II ( $P < 0.001$ ) and with Ketac Universal ( $P = 0.037$ ). Significant differences were identified between Vitremer

**Table 3: Comparison of the color variation ( $\Delta E$ ) caused by the beverages in each restorative material according to immersion time**

Time	Beverage	n	Beautiful II					Vitremer					Ketac universal				
			Mean	SD	Median	IQR	*P	Mean	SD	Median	IQR	*P	Mean	SD	Median	IQR	*P
1 hour	Coca-Cola®	15	1.94	0.53	1.86 <sup>A</sup>	1.07	0.001	4.07	2.17	3.20	3.30	0.607	2.60	1.16	2.14 <sup>A</sup>	2.20	0.001
	Coffee	15	3.91	1.31	4.08 <sup>B</sup>	1.77		3.46	1.75	4.04	2.68		4.82	1.96	5.30 <sup>B</sup>	3.11	
	Red wine	15	4.14	1.31	4.28 <sup>B</sup>	1.68		3.14	1.68	3.22	3.25		4.16	1.42	4.43 <sup>B</sup>	2.04	
24 h	Coca-Cola®	15	3.31	1.04	3.12 <sup>A</sup>	2.07	<0.001	6.11	1.65	5.71	2.50	0.276	4.44	1.25	4.59 <sup>A</sup>	1.68	0.004
	Café	15	7.44	1.86	6.99 <sup>B</sup>	3.57		5.06	2.18	4.54	3.88		6.86	1.93	7.27 <sup>B</sup>	2.81	
	Red wine	15	10.74	2.67	10.38 <sup>B</sup>	4.39		6.22	2.27	6.52	3.35		6.25	1.99	5.89 <sup>B</sup>	3.73	
1 week	Coca-Cola®	15	4.58	1.62	5.04 <sup>A</sup>	2.44	<0.001	7.53	2.22	7.04	4.18	0.134	6.67	2.23	6.01 <sup>A</sup>	3.01	0.002
	Café	15	11.51	1.66	11.27 <sup>B</sup>	2.66		7.69	2.37	7.82	3.38		9.99	1.76	10.43 <sup>B</sup>	3.69	
	Red wine	15	21.47	2.94	21.03 <sup>C</sup>	4.13		8.98	1.48	8.26	2.46		9.27	3.06	8.91 <sup>B</sup>	4.48	

n = sample size, SD = standard deviation, IQR = interquartile range

\*Based on Kruskal-Wallis H-test,  $P < 0.05$  (significant differences); different letters in each column of the median indicate significant differences ( $P < 0.05$ ) according to Dunnett's post hoc with Bonferroni correction

**Table 4: Comparison of color variation ( $\Delta E$ ) of restorative materials according to the type of beverage and time**

Time	Cement	n	Coca-Cola®					Coffee					Red wine				
			Mean	SD	Median	IQR	*P	Mean	SD	Median	IQR	*P	Mean	SD	Median	IQR	*P
1 hour	Beautiful II	15	1.94	0.53	1.86 <sup>A</sup>	1.07	0.003	3.91	1.31	4.08	1.77	0.174	4.14	1.31	4.28	1.68	0.146
	Vitremer	15	4.07	2.17	3.20 <sup>B</sup>	3.30		3.46	1.75	4.04	2.68		3.14	1.68	3.22	3.25	
	Ketac	15	2.60	1.16	2.14 <sup>A,B</sup>	2.20		4.82	1.96	5.30	3.11		4.16	1.42	4.43	2.04	
24 h	Beautiful II	15	3.31	1.04	3.12 <sup>A</sup>	2.07	<0.001	7.44	1.86	6.99 <sup>A</sup>	3.57	0.015	10.74	2.67	10.38 <sup>A</sup>	4.39	<0.001
	Vitremer	15	6.11	1.65	5.71 <sup>B</sup>	2.50		5.06	2.18	4.54 <sup>B</sup>	3.88		6.22	2.27	6.52 <sup>B</sup>	3.35	
	Ketac	15	4.44	1.25	4.59 <sup>A</sup>	1.68		6.86	1.93	7.27 <sup>A,B</sup>	2.81		6.25	1.99	5.89 <sup>B</sup>	3.73	
1 week	Beautiful II	15	4.58	1.62	5.04 <sup>A</sup>	2.44	0.002	11.51	1.66	11.27 <sup>A</sup>	2.66	<0.001	21.47	2.94	21.03 <sup>A</sup>	4.13	<0.001
	Vitremer	15	7.53	2.22	7.04 <sup>B</sup>	4.18		7.69	2.37	7.82 <sup>B</sup>	3.38		8.98	1.48	8.26 <sup>B</sup>	2.46	
	Ketac	15	6.67	2.23	6.01 <sup>B</sup>	3.01		9.99	1.76	10.43 <sup>A</sup>	3.69		9.27	3.06	8.91 <sup>B</sup>	4.48	

n = sample size, SD = standard deviation, IQR = interquartile range

\*Based on Kruskal-Wallis H-test,  $P < 0.05$  (significant differences); different letters in each column of the median indicate significant differences ( $P < 0.05$ ) according to Dunnett's post hoc with Bonferroni correction



**Table 5: Comparison of color variation ( $\Delta E$ ) over time according to type of restorative material and beverage**

Cement	Beverage	n	1 h (X)			24 h (Y)			1 week (Z)			*P	Multiple comparisons		
			Median	IQR	IQR	Median	IQR	IQR	Median	IQR	IQR		(X) vs (Y)	(X) vs (Z)	(Y) vs (Z)
Beautifulfil II	Coca-Cola®	15	1.86	1.07	2.07	3.12	2.07	2.44	5.04	2.44	2.44	<0.001	0.019	<0.001	0.019
	Coffee	15	4.08	1.77	3.57	6.99	3.57	2.66	11.27	2.66	2.66	<0.001	0.019	<0.001	0.019
	Red wine	15	4.28	1.68	4.39	10.38	4.39	4.13	21.03	4.13	4.13	<0.001	0.019	<0.001	0.019
Vitremer	Coca-Cola®	15	3.20	3.30	2.50	5.71	2.50	4.18	7.04	4.18	4.18	<0.001	0.019	<0.001	0.019
	Coffee	15	4.04	2.68	3.88	4.54	3.88	3.38	7.82	3.38	3.38	<0.001	0.019	<0.001	0.019
	Red wine	15	3.22	3.25	3.35	6.52	3.35	2.46	8.26	2.46	2.46	<0.001	0.019	<0.001	0.019
Ketac	Coca-Cola®	15	2.14	2.20	1.68	4.59	1.68	3.01	6.01	3.01	3.01	<0.001	0.053	<0.001	0.010
	Coffee	15	5.30	3.11	2.81	7.27	2.81	3.69	10.43	3.69	3.69	<0.001	0.019	<0.001	0.019
	Red wine	15	4.43	2.04	3.73	5.89	3.73	4.48	8.91	4.48	4.48	<0.001	0.019	<0.001	0.019

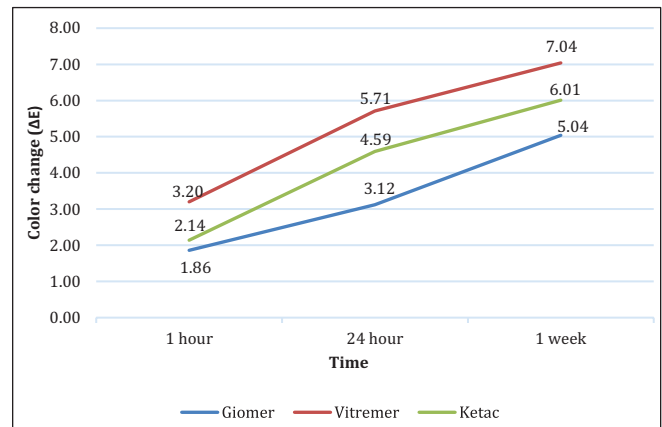
n = sample size, IQR = interquartile range

\* Based on Friedman's test,  $P < 0.05$  (significant differences)

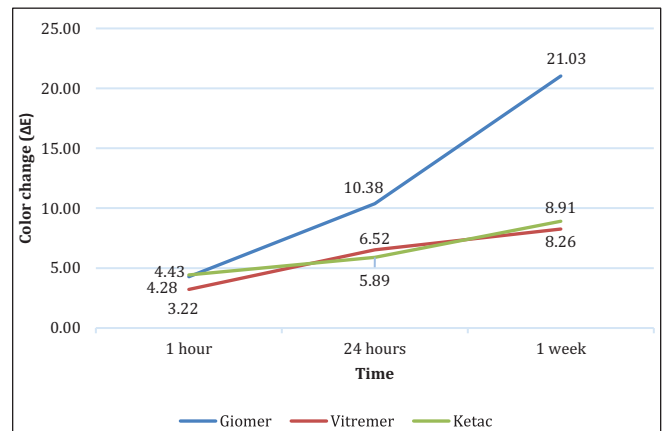
\*\* Based on post hoc with Bonferroni correction, significant differences ( $P < 0.05$ )

and Beautifulfil II ( $P = 0.017$ ) when exposed to coffee. Significant differences were observed when comparing Beautifulfil II with Vitremer ( $P < 0.001$ ) and with Ketac Universal ( $P < 0.001$ ) when exposed to red wine. At 1 week of exposure to Coca-Cola® and red wine, significant differences were observed when comparing Beautifulfil II with Ketac Universal ( $P < 0.05$ ) and with Vitremer ( $P = 0.002$ ). In coffee exposure, significant differences were observed when comparing Vitremer with Ketac Universal ( $P = 0.049$ ) and with Beautifulfil II ( $P < 0.001$ ). Finally, Coca-Cola® and coffee pigmented Beautifulfil II and Vitremer significantly less ( $P = 0.002$  and  $P < 0.001$ , sequentially) than the other materials. Red wine pigmented Beautifulfil II significantly more ( $P < 0.001$ ) than the other restorative materials [Table 4].

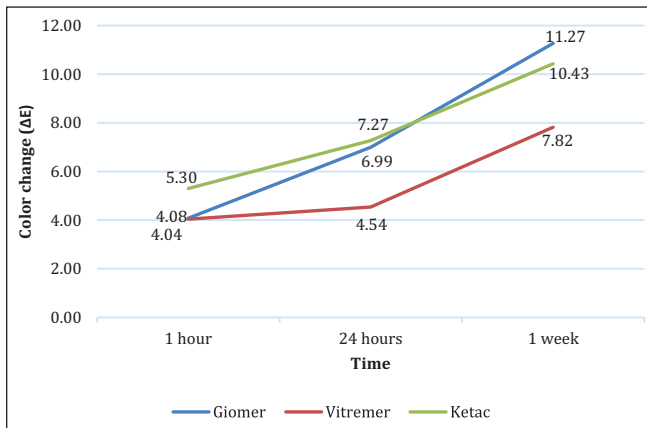
When contrasting the color variation ( $\Delta E$ ) over time was compared, it was discovered that the three restorative materials exposed to the three beverages consistently presented a significant change ( $P < 0.001$ ). However, there was no significant change in color variation for Ketac Universal between 1h and 24h of exposure to Coca-Cola® ( $P = 0.053$ ) [Table 5, Figures 2–4].



**Figure 2:** Color variation in each restorative material exposed to Coca-Cola® over time



**Figure 3:** Color variation in each restorative material exposed to red wine over time



**Figure 4:** Color variation in each restorative material exposed to coffee over time

## DISCUSSION

The present study evaluated the color stability of a giomer, a resin-modified glass ionomer and a conventional glass ionomer exposed to different beverages and at different immersion times. It was obtained that Beautifil II and Ketac Universal presented significant differences when immersed in coffee, red wine and Coca-Cola® for 1 h, 24 h, and 1 week. Likewise, Vitremer did not show significant differences when exposed to Coca-Cola®, coffee and red wine at all times evaluated. The null hypothesis was rejected based on the findings.

Cervical carious or non-carious lesions have a multifactorial origin, so there is no consensus on how to manage them; however, it is very appropriate to restore them to avoid loss of tooth structure, excessive sensitivity, exposure of the dental pulp, as well as to improve aesthetics. Marginal loss, but especially marginal discoloration, are the main defects in cervical restorations (Class V). Both deficiencies threaten aesthetics, especially when they are in the anterior sector. Ionomers are a good alternative to restore these lesions due to their good properties; however, due to the porosity of the material, aesthetics are compromised.<sup>[12,13]</sup>

To evaluate the colorimetric properties of materials objectively, the CIE  $L^*a^*b^*$  system and the digital spectrophotometer are frequently used. This eliminates subjective variability in color perception and helps to consistently establish color changes over time,<sup>[4,17]</sup> taking into account that the literature establishes  $(\Delta E) \leq 3.3$  as a clinically acceptable value of color variation.<sup>[16,18]</sup>

The findings obtained in the present study showed that Beautifil II and Ketac Universal had significant differences when submerged for 1 h, 24 h, and 1 week to Coca-Cola®, coffee, and red wine. This can be attributed to the softening and dissolution of the matrix surrounding the glass particles resulting in the dissolution of the silica hydrogel layer, which would cause a rough surface that would increase pigment adsorption and lead to staining.<sup>[20]</sup>

Previous research found that the composition of restorative materials has a significant impact on their color stability. Because of the filler particles, resin-based composites offer superior color stability than ionomer-based materials.<sup>[21,22]</sup> Temperature and acidity are two elements connected to staining solutions that can influence the outcome.<sup>[18,23,24]</sup> According to Al-Samadani,<sup>[23]</sup> when exposed to low pH (acidic) settings, glass filler particles tend to slip out of the material and suffer matrix disintegration. Mohamed *et al.*<sup>[25]</sup> reported that acidity would increase filler erosion and surface roughness thus compromising color stability by facilitating pigment adsorption.

When evaluating the effects of beverages with different pH, it was observed that coffee (pH: 5.45) and red wine (pH: 3.82) caused greater color variation compared to Coca-Cola® (pH: 2.4) for both the giomer (Beautifil II) and the conventional ionomer (Ketac Universal). This was in disagreement with that reported by Sajini *et al.*<sup>[21]</sup> who stated that pH differences in beverages do not influence color stability. However, with the results obtained we can conclude that the acids of coffee and red wine could have affected the material and stained it, because the acid attack could have altered the ionomer matrix causing the release of metal cations from the glass particles, thus generating a greater surface roughness and finally causing the pigments to be trapped on the surface of the material.<sup>[24]</sup> Unlike Coca-Cola®, coffee and wine may have caused a greater color change due to the presence of flavonols, also known as tannins, which during oxidation are converted to aflavins and arubigins. These chemical elements give red wine and coffee their distinctively dark hue and powerful flavors.<sup>[25,26]</sup> Ardu *et al.*<sup>[27]</sup> reported that coffee has a yellow coloring pigment that has different polarities and a strong affinity for polymers. These characteristics could be the cause of the color shift. Coca-Cola®, despite having the lowest pH of the staining solutions tested, it may induce more degradation but not as much color change as coffee and wine, owing to the absence of yellow pigments in its composition.<sup>[17]</sup> The current study's findings agreement with earlier research studies by Valizadeh *et al.*<sup>[17]</sup> and Sajini *et al.*<sup>[21]</sup> in which coffee and wine produced greater color alteration than coca cola.

In the present study, it was found that the Beautifil II giomer presented significant differences with the other materials tested when immersed for 1 h, 24 h, and 1 week of immersion in Coca-Cola®, coffee, and red wine. Gionomers such as Beautifil II are fluoride releasing materials. This factor could have created voids within the matrix and possibly roughness, thus contributing to lower color stability due to pigment retention.<sup>[21]</sup> Gonolul *et al.*<sup>[28]</sup> and Ozdas *et al.*<sup>[22]</sup> reported that the susceptibility of this giomer to staining may be affected by its levels of hydrophilicity and water absorption. If a compound can absorb water, it can also absorb other pigmented fluids that could lead to discoloration. In addition, Beautifil II

giomer is known to have a hydrophilic resin matrix that does not include urethane dimethacrylate monomers which are more hydrophobic,<sup>[21,22,28]</sup> thus favoring fluid adsorption and thus discoloration.

The conventional Ketac Universal ionomer showed significant differences in color variation as did the Beautifil II giomer. It has been reported as an advantage that the benzoic acid present in the copolymeric acid of Ketac Universal could produce a mechanical interlocking phenomenon as a result of hardening. This effect would make the ionomer less hydrolytic and more stable to color change as well as conferring good chemical resistance in the oral environment.<sup>[20,25]</sup>

According to Mohamed *et al.*,<sup>[25]</sup> most silicate glasses are resistant to acid assaults. They did, however, point out that when the silicate's ionic characteristics rise, the glass becomes more vulnerable to acid attacks. As a result, any factor that reduces the ionomer's hydrolytic stability reduces its hardness and color stability while also increasing its deterioration. This would happen especially in acidic conditions such as those provided by the pigments used in the present study. Haque *et al.*<sup>[20]</sup> indicated that color changes can occur as a result of fluoride ion leaching from calcium fluorosilicate glass. This occurs as a result of ion exchange between the material and the pigment solution, impacting the material's surface and structural integrity. In addition, Bajpai *et al.*<sup>[29]</sup> and Pacifici *et al.*<sup>[30]</sup> reported that when the preparation of a material requires handling and mixing (as occurs with powder and liquid) there is an increased risk of incorporation of air bubbles and thus increased porosity. This would result in higher surface roughness and higher pigment retention leading to discoloration.

The Vitremer modified ionomer did not show significant differences when exposed to Coca-Cola®, coffee, and red wine at all times evaluated. This could be due to the application of the finishing gloss. The use of this protector reduces surface roughness. In addition, it has been strongly recommended to protect the surface of ionomers to preserve the water balance in the system.<sup>[30]</sup> Karaođlanođlu *et al.*<sup>[31]</sup> reported that if the ionomer matrix absorbs water, it will become chalky and erode rapidly. This finding reinforces the idea that ionic surface protection is required for these materials in order to maintain the water balance in the system and provide enough early protection against absorption or loss of water and pigments inherent in the materials.

The design of this study had as strength the handling of a digital spectrophotometer to adequately evaluate the color change thus reducing information bias.<sup>[18]</sup> Also, the Sof-Lex polishing system™ was chosen because it has been shown to significantly reduce surface irregularities in contrast to other polishing techniques. Achieving a smooth and polished surface has been described as an

effective way to improve color stability in restorations in general.<sup>[32-35]</sup> In addition, the chosen polishing system was employed as a standard protocol due to its capacity to create smooth, chemically resistant surfaces.<sup>[36,37]</sup> Finally, to allow standardized color monitoring throughout the present study, temperature was controlled as it is reported to act as an aging factor leading to increased pigmentation.<sup>[21]</sup>

It should be acknowledged as a weakness that the current study, being *in vitro*, does not allow the results obtained to be completely predictable in a clinical setting because there are different factors that can affect the stability of the color of the restorative materials when they are in the oral cavity. These factors may include the salivary film, and the impact of certain foods that are challenging to replicate in an *in vitro* setting. Another disadvantage was that the specimens were immersed under a static staining protocol, unlike in the oral cavity, where conditions are dynamic and intermittent, which precludes staining of the tooth and restoration.,<sup>[17]</sup> as a result, the severity of staining that occurs *in vitro* is greater than that observed in the clinical environment. Finally, given the limits and characteristics utilized in this study, additional research is recommended to analyze the discoloration of the materials employed while taking into account the usage of various polishing processes, surface roughness, and protective coatings (e.g. gloss) at different immersion times, as well as simulate the temperature changes that occur in the oral cavity with thermocycling.

## CONCLUSION

Coffee and red wine significantly varied the color of Beautifil II and Ketac Universal over time. Beautifil II and Ketac Universal showed significantly more pigmentation with red wine and less with Coca-Cola® at 1 week immersion. Vitremer showed no significant differences when exposed to Coca-Cola®, coffee and red wine at all times tested. There were clinically acceptable variations for all three restorative materials immersed in Coca-Cola® for 1 hour. This clinical threshold was only maintained for the Beautifil II giomer up to 24h of immersion in the same beverage.

## Acknowledgement

We thank the team of the “Materiales Dentales II” research line of the School of Stomatology of the Universidad Privada San Juan Bautista, Peru, for their constant support in the preparation of this manuscript.

## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.



## Authors contributions

Conceptualization, BAM and CGA; Data curation, LCR; Formal analysis, CCR; Investigation, BAM, CGA, MLC and CCR; Methodology, LCR, GDZ and CCR; Project administration, BAM, CGA and CCR; Resources, BAM, CGA and LCG; Data analysis, CCR; Supervision, CCR; Writing – original draft, BAM, CGA, LCR and GDZ; Writing – review & editing, LCG, MLC, GDZ and CCR.

## Ethical policy and Institutional Review board statement

This study was exempted from protocol review by the institutional ethics committee of the Universidad Privada San Juan Bautista, as it did not put human life at risk. However, it approved the execution of the project with official letter No. 282-2022-CIEI-UPSJB.

## Patient declaration of consent

Not applicable.

## Data availability statement

The data presented in this study are available on request from the corresponding author.

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