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Research Article

Impact of Common Pediatric Medications on Color Stability of Esthetic Restorative Materials: An In Vitro Study

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Abstract
Aim: To evaluate the effect of commonly prescribed pediatric medications on the color stability of two esthetic restorative materials, glass ionomer cement (GIC) and composite resin, using an in vitro model incorporating thermocycling.

Materials and Methods: The total of 160 specimens (GIC and composite resin) were prepared and immersed in various pediatric medications, including analgesics, antibiotics, anticonvulsants, bronchodilators, cough suppressants, multivitamins, and a control solution. All specimens were subjected to thermocycling. Color changes (ΔE values) were measured using a spectrophotometer before and after exposure.

Results: Significant color changes were observed in both materials, particularly in the multivitamins and the cough suppressant. GIC generally exhibited higher ΔE values than composite resin. After thermocycling, the composite resin exhibited a slight increase in discoloration, whereas the GIC values largely remained stable. Overall, the composite resin maintained superior color stability.

Conclusion: Pediatric medication can compromise the color stability of esthetic restorative materials. GIC were more susceptible to staining, although thermocycling had a minimal impact on discoloration. The composite resin exhibited better performance both before and after thermocycling, underscoring its clinical utility in esthetic pediatric dentistry. These findings emphasize the importance of selecting restorative materials based on both chemical and thermal resistances.

Keywords: Color stability, Pediatric medications, Glass ionomer cement, Composite resin, Thermocycling

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Introduction

In modern pediatric dentistry, esthetic outcomes are essential rather than optional. An increasing number of children and their caregivers seek restorative procedures that preserve the natural appearance and function of teeth. Owing to their favorable physical properties, ease of handling, and esthetic appearance, restorative materials—such as glass ionomer cement (GIC) and composite resin—are frequently employed.[1]

Color stability, defined as the ability of a material to retain its original color over time, is a key determinant of the clinical success of a restoration. This is particularly critical for anterior teeth, where even minor discoloration can present esthetic concerns. Discoloration of dental restorations may lead to patient dissatisfaction, increased dental visits, and premature replacement of restorations, factors that contribute to elevated treatment costs, extended treatment duration, and heightened dental anxiety in pediatric patients.[2]

The longevity and esthetics of restorative materials are significantly affected by the oral environment. While many studies have examined the impact of dietary substances such as coffee, tea, and acidic beverage son color stability, the influence of pediatric medications has received relatively little attention despite their frequent and prolonged use in children. Many of these liquid medications have high sugar content, low pH, and artificial colorants to enhance flavor and patient compliance. They are commonly prescribed for chronic conditions such as asthma, epilepsy, and nutritional deficiencies.[3,4]
The chemical interactions between these formulations and restorative materials may lead to increased pigment retention, surface erosion, and extrinsic staining. Furthermore, medications, such as cough syrups, antibiotics, and multivitamins, are often administered multiple times daily over extended periods. This may potentially lead to clinically perceptible discoloration of restorations, raising an important clinical question: "To what extent do commonly used pediatric medications compromise the esthetic stability of restorative materials?"[5,6]

GICs are commonly used in pediatric dentistry because of their chemical adhesion to the enamel and dentin, fluoride release, and ease of application, particularly in children who are difficult to manage. However, GICs are more susceptible to discoloration because of their higher porosity and water sorption.[7] In contrast, composite resins—especially nanohybrid formulations—offer better surface polishability and esthetic outcomes, although their stability under prolonged chemical exposure remains uncertain.[8]

The adverse effects of pediatric syrups on restorative materials have been documented in several studies. For example, Mehta et al. and Ravishankar et al. found that pediatric medications, particularly those with low pH and coloring agents, could significantly compromise the color of restorations in vitro.[9,10] However, evidence of the degree of staining induced by different medication types and the relative resistance of GIC versus composite resin is inconsistent.[11]
Despite the growing interest in the esthetic performance of pediatric restorations, few studies have simultaneously investigated the effects of pediatric liquid medications and thermocycling on the color stability of restorative materials.[32]

Therefore, this in vitro study aimed to evaluate and compare the discoloration of GIC and composite resins after exposure to commonly prescribed pediatric syrups, with and without thermocycling, to better simulate intraoral conditions.

Materials and Methods
This in vitro study was approved by the Ethics Committee of the Faculty of Dentistry at Mansoura University (Approval No. A0407024PP). This study evaluated the effects of commonly prescribed pediatric medications on the color stability of two restorative materials: GIC and composite resin. The study was conducted in the Department of Pediatric Dentistry in the laboratory of the biomaterial department, Faculty of Dentistry, Mansoura University.

Sample Size Calculation
To evaluate the objective, color stability data were analyzed using one-way analysis of variance (ANOVA). A total of 160 samples were divided equally into two groups (80 samples each). Each group was further subdivided into eight subgroups (10 samples per subgroup). This sample size allowed for the detection of an effect size of 0.17 with a statistical power of 90% ($1 - \beta = 0.90$) and a significance level of $p \leq 0.05$. Based on this calculation, 10 samples per subgroup provided a 90% probability of correctly rejecting the null hypothesis, assuming that a true effect exists. The sample size was calculated using the G*Power software (version 3.1.9.7).[13, 14]

Materials Used in the Study
Fuji II LC Capsules, shade A2 (GC Corporation, Tokyo, Japan) were used as RMGIC specimens, and a nanohybrid composite resin (Tetric N-Ceram, shade A2, Ivoclar Vivadent, Zurich, Switzerland) was used for the composite specimens (Table 1). Seven liquid drugs commonly administered to children were tested. The pH levels were measured using a pH meter (Zhengzhou, China) (Table 2).

Table 1. Restorative materials used in this study

Product	Manufacturer	Composition	Batch number
Resin-reinforced GIC (Fuji II LC Capsules, shade A2)	GC Corporation, Tokyo, Japan	58 wt% fluoroaluminosilicate, methacrylate, hydroxyethyl, polyacrylic acid, and water.	2406193
Composite resin (nanohybrid, shade A2)	Ivoclar, Zurich, Germany	19–20 wt% dimethacrylates; fillers include barium glass, ytterbium trifluoride, mixed oxide, and copolymers (80–81 wt%)	Z05NHZ

Table 2. Pediatric liquid medications used in this study

	Group	Generic Name	Brand Name	pH
1	Analgesic	Paracetamol	CETAL	5.5
2	Analgesic (cold symptoms)	Acetaminophen + Chlorpheniramine Maleate + Pseudoephedrine Hydrochloride	123	4.4
3	Antibiotics	Amoxicillin + Clavulanic Acid	Augmentin	4.5
4	Anticonvulsant	Phenytoin	IPANTEN	5.5
5	Cough Syrup	Dried Ivy Leaf Extract	IVROSPAN	5.1
6	Bronchodilator	Albuterol	Ventolin	3.9
7	Multivitamins	Multivitamins	MARVIT	4.1

Study Design

This in vitro experimental study compared the effects of commonly prescribed pediatric medications on the color stability of esthetic restorative materials used in pediatric dentistry. A total of 160 specimens were fabricated using two types of restorative materials (80 specimens per material). Each material group was randomly divided into eight solution groups (n = 10), based on the pediatric drug formulations tested. The groups included: 1. Analgesics (Paracetamol) and 2. (Acetaminophen), 3. Antibiotics (Amoxicillin + Clavulanic Acid), 4. Anticonvulsant (Phenytoin), 5. Bronchodilator (Albuterol), 6. Cough Syrup (Prospan), 7. Multivitamin (Marvit), and 8. Control (distilled water, pH 5.7). Each solution group was further divided into two subgroups (brushed and unbrushed; n = 10 each).

Specimen Preparation:

A total of 160 disk-shaped specimens (80 from each material), each with a diameter of 10 mm and thickness of 2 mm, were prepared using a split resin mold.[13] To prevent air entrapment and void formation, a cellulose acetate matrix strip was placed over the mold and compressed between two glass slides, each 1 mm thick. Two restorative materials were used: resin-based composites and resin-reinforced glass ionomer cement (RMGIC). Both materials were prepared according to the manufacturers' instructions.

For the **RMGIC specimens**, *Fuji II LC Capsules, shade A2* (GC Corporation, Tokyo, Japan), were used. Each capsule was activated by depressing the plunger until the internal barrier was broken. The capsule was then mixed in an amalgamator (Gnatus Amalga Mix 2, Brazil) for 10 seconds at 4000 rpm. Immediately after mixing, the material was inserted into the mold using a capsule applicator (Generic China, model FD-NS002) .The specimens were light-cured through a Mylar strip and glass slide using a light-emitting diode (LED) curing unit (3M ESPE Dental, Dublin, Ireland) with an output intensity of 1200 mW/cm^2. Curing was applied for 20 s per surface, with the tip of the light source placed in direct contact with the upper glass slide (0 mm distance).

For composite specimens a nanohybrid composite resin (*Tetric N-Ceram, shade A2*; *Ivoclar Vivadent, Zurich, Switzerland*) was used. The material was dispensed directly into a split resin mold in a single increment to produce disc-shaped specimens measuring 10 mm in diameter and 2 mm in thickness. To minimize air entrapment and surface irregularities, the composite was carefully inserted using a plastic filling instrument. A cellulose acetate Mylar strip was then placed over the material and pressed between two glass slides, each 1 mm thick, to flatten the surface and simulate clinical adaptation. The specimens were polymerized using a light-emitting diode (LED) curing unit (3M ESPE Dental, Dublin, Ireland) with a light intensity of 1200 mW/cm^2. The curing tip was positioned in direct contact with the upper glass slide (0 mm distance), and each surface was cured for 20 s in accordance with the manufacturer's instructions to ensure complete polymerization.

All the composite and GIC specimens were polished sequentially using aluminum oxide polishing disks (Sof-Lex, 3M ESPE, St. Paul, MN, USA) attached to an electric handpiece operating at 15,000 rpm. Each disk grade (coarse, medium, fine, and superfine) was applied for 10 s per specimen. To ensure complete polymerization and material maturation, all specimens were stored in distilled water at 37 °C for 24 hours prior to testing (Fig. 1).

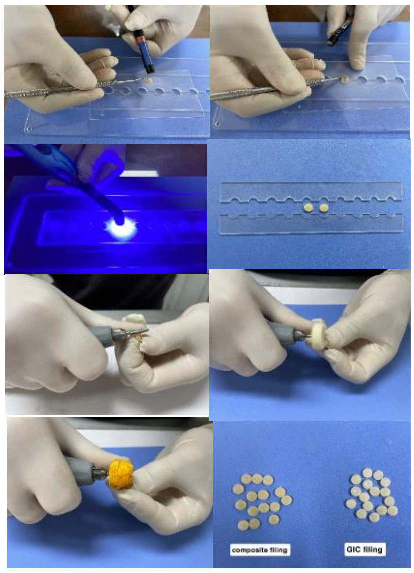


Fig. 1. Preparation of specimens.

Color-Change Measurement:

The specimens were rinsed with distilled water for 5 s and dried with tissue paper prior to evaluation using a spectrophotometer to determine baseline color values. The spectrophotometer was calibrated with its own calibration device before color measurements were recorded. Measurements were performed at the center of each specimen using a clinical spectrophotometer (***Labymos, model DS 200***; ***CHNSpec Technology Co.,***

Ltd., Holland). The aperture size was set to 3 mm and each specimen was precisely aligned with the device. All the measurements were conducted against a white background following the CIE Lab* color space under the standard illuminant D65/10°. Each specimen was measured three times using the CIE L*a*b* system.

In this system, color is defined by three coordinates: *L** represents the lightness (value), a* represents the red-green axis, and b* represents the yellow-blue axis. Along the vertical (neutral) axis, the values range from black (L = 0) to white (L = 100), with varying grey levels in between.

Drug Immersion:

Following baseline measurements, the specimens (n = 10 per material) were immersed in 10 mL of undiluted pediatric liquid medication in separate test tubes. Immersion was performed for one week, with the specimens agitated for 2 min every 8 h. Solutions were refreshed daily. Between immersion intervals, the specimens were stored in artificial saliva, prepared at the Mansoura University by dissolving potassium chloride, sodium phosphate, sodium fluoride, and calcium chloride in a small volume of water. Methylparaben and propylparaben were dissolved in warm water, cooled, and then mixed with the salt solution.

To ensure consistent temperature, a thermometer (JiangSu YuYue Medical, Danyang, China) was used to verify that all solutions were maintained at room temperature.

After each immersion cycle, the specimens were rinsed under running water and stored in artificial saliva until the next application. After a one-week immersion period, the specimens were dried and prepared for color measurements.

Color Measurement After Drug Immersion:

Post-immersion color was evaluated using a reflective spectrophotometer (***Labymos, model DS 200***; ***CHNSpec Technology Co., Ltd., Holland***). The degree of color change between the baseline and post-immersion values was expressed in ΔE units. The total color difference (ΔE_1) was calculated based on the L*, a*, and b* coordinates using the following equation:

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{k_C S_C}\right)\left(\frac{\Delta H'}{k_H S_H}\right)}$$

Where:

ΔL′ = lightness difference

ΔC′ = chroma difference

ΔH′ = hue difference

SL, SC, SH = weighting functions

RT = rotation term (accounts for interaction between chroma and hue)

kL, kC, and kH = parametric factors (set to 1 under standard viewing conditions)

Thermocycling:

All specimens underwent thermocycling using a thermocycler with alternating water baths maintained at 5 °C and 55 °C. Each specimen was immersed in a cold water bath (5 °C), followed by immersion in a hot water bath (55 °C) for 30 s per bath, with a dwell time of 10 s between transfers. A total of 500 cycles were completed to simulate thermal stresses representative of intraoral conditions.

Color Change Measurement After Thermocycling:

Following thermocycling, all specimens were re-evaluated using a reflective spectrophotometer (***Labymos, model DS 200***; ***CHNSpec Technology Co., Ltd., Holland***) to measure the post-thermocycling color values. The color difference between the baseline and post-thermocycling values was calculated and denoted as ΔE_2.

To assess the clinical relevance of the measured color differences, perceptibility and acceptability thresholds established in a multicenter clinical study involving 175 observers—including dentists, dental students, laboratory technicians, and laypersons—were adopted.[33] The thresholds were defined as follows:

Perceptibility threshold (PT): $\Delta E_{00} = 0.8$

Acceptability threshold (AT): $\Delta E_{00} = 1.8$

Based on these criteria:

$\Delta E_{00} < 0.8$ was considered **imperceptible**

$0.8 \leq \Delta E_{00} < 1.8$ was considered **perceptible but clinically acceptable**

$\Delta E_{00} \geq 1.8$ was considered **clinically unacceptable**

These thresholds were used to classify the magnitude of color change and evaluate the visual significance of drug exposure and thermocycling on esthetic restorative materials.

Statistical Analysis

Data were analyzed using one-way ANOVA, followed by post hoc tests to compare ΔE values among the different drug groups.

Results:

Table 3 presents the intergroup comparison of color stability (ΔE) between GIC and composite resin following drug exposure and thermocycling. The ΔE values for both materials varied significantly depending on the type of pediatric medication. Among the tested medications, multivitamins resulted in the highest level of discoloration, with a mean ΔE of 6.69 ± 2.48 for GIC and 1.64 ± 0.62 for composite resin. This difference was statistically significant ($p < 0.001$), indicating that multivitamins were the most aggressive staining agents. Paracetamol caused moderate discoloration, with ΔE values of 1.98 ± 0.93 for GIC and 1.26 ± 0.58 for composite resin ($p = 0.026$). In contrast, acetaminophen did not cause a statistically significant difference in the color change between the two materials ($p = 0.711$).

Both Augmentin and phenytoin produced significantly greater discoloration in GIC compared to that in composite resin ($p = 0.017$ and $p = 0.012$, respectively). The mean ΔE values for GIC were 2.61 ± 1.35 (Augmentin) and 2.45 ± 1.52 (phenytoin), while composite values were notably lower at 1.35 ± 1.13 and 1.25 ± 0.53, respectively. Albuterol also showed a statistically significant difference, with GIC exhibiting a mean ΔE of 2.15 ± 0.59, compared to 1.15 ± 0.48 for composite resin ($p < 0.001$). Ivorspan (Prospan) resulted in ΔE values of 2.31 ± 0.69 for GIC and 1.93 ± 0.92 for composite; however, this difference was not statistically significant ($p = 0.234$). The control group (distilled water) demonstrated the lowest ΔE values in both materials, confirming that the observed color changes were primarily due to the chemical properties of the tested medications.

On average, the mean ± SD ΔE values were consistently higher in the GIC group than in the composite group across all drug types, emphasizing the influence of restorative material type on discoloration resistance. Statistically significant differences in color change were found between the GIC and the composite for paracetamol, Augmentin, phenytoin, albuterol, and multivitamins ($p < 0.05$). The most pronounced reduction was observed with multivitamins, where switching from GIC to composite resin reduced the mean ΔE by approximately 75%.**After thermocycling:** The mean ± SD ΔE values were generally higher in the GIC group compared to the composite resin group for most medications, similar to the post-drug immersion stage, with the exception of acetaminophen. Statistically significant differences in color change between the two restorative materials were observed for all medications ($p < 0.05$) except for paracetamol. Multivitamins demonstrated the greatest reduction in mean ΔE, with an approximate decrease of 70.7% when switching from GIC to composite resin.

Table 3. Mean ± SD and Intergroup Comparison of Color Stability (ΔE) Between Glass Ionomer Cement (GIC) and Composite Resin.

Medication	After Drug Exposure			After Thermocycling		
	GIC (Mean ± SD)	Composite (Mean ± SD)	p-value	GIC (Mean ± SD)	Composite (Mean ± SD)	p-value
Paracetamol	1.98 ± 0.93	1.26 ± 0.58	0.026*	1.94 ± 0.64	1.38 ± 0.98	0.096
Acetaminophen	2.34 ± 1.26	2.15 ± 1.45	0.711	1.27 ± 0.51	1.96 ± 0.89	0.024*
Augmentin	2.61 ± 1.35	1.35 ± 1.13	0.017*	2.61 ± 1.29	1.43 ± 1.21	0.024*
Phenytoin	2.45 ± 1.52	1.25 ± 0.5	0.012*	2.18 ± 1.38	1.08 ± 0.55	0.014*
Ivorspan	2.31 ± 0.69	1.93 ± 0.92	0.234	2.17 ± 0.97	1.27 ± 0.68	0.011*
Albuterol	2.15 ± 0.59	1.15 ± 0.48	<0.001*	2.16 ± 0.77	1.32 ± 0.92	0.019*
Multivitamin	6.69 ± 2.48	1.64 ± 0.62	<0.001*	3.83 ± 1.63	1.12 ± 0.52	<0.001*
Control	-	-	-	2.64 ± 1.1	0.9 ± 0.42	<0.001*

** Statistically significant at p ≤ 0.05*

Table 4 presents the intragroup comparison of color stability (ΔE) for each restorative material between two time points: after drug exposure and after thermocycling.

GIC: The mean ± SD ΔE for GIC specimens was as follows: Paracetamol: 1.98 ± 0.93 after drug treatment; 1.94 ± 0.64 after thermocycling, Acetaminophen: 2.34 ± 1.26 after drug treatment; 1.27 ± 0.51 after thermocycling, Augmentin: 2.61 ± 1.35 after drug treatment; 2.61 ± 1.29 after thermocycling, Phenytoin: 2.45 ± 1.52 after drug treatment; 2.18 ± 1.38 after thermocycling, Ivorspan: 2.31 ± 0.69 after drug treatment; 2.17 ± 0.97 after thermocycling, Albuterol: 2.15 ± 0.59 after drug treatment; 2.16 ± 0.77 after thermocycling, Multivitamins: 6.69 ± 2.48 after drug treatment; 3.83 ± 1.63 after thermocycling, and control (distilled water): 2.64 ± 1.10 after thermocycling

Statistically significant differences between the two time points were observed only for acetaminophen ($p < 0.05$) and multivitamin ($p < 0.05$).

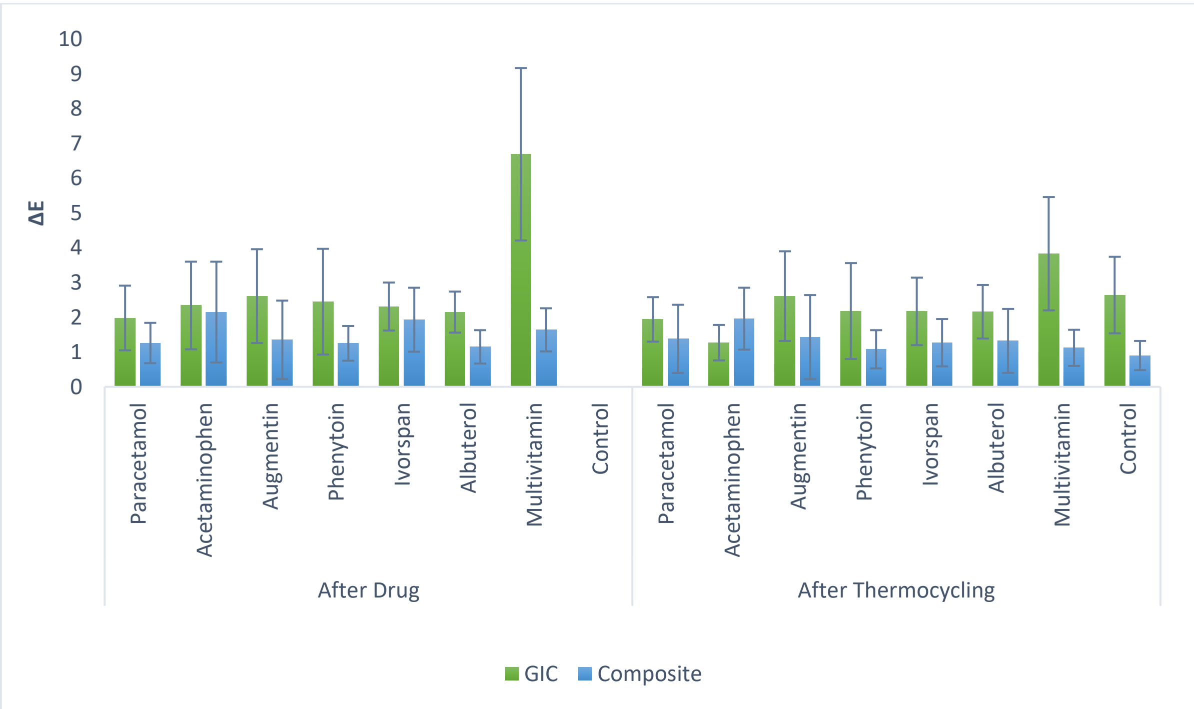
Composite resin: The mean ± SD ΔE for composite specimens was as follows: Paracetamol: 1.26 ± 0.58 after drug treatment; 1.38 ± 0.98 after thermocycling, Acetaminophen: 2.15 ± 1.45 after drug treatment; 1.96 ± 0.89 after thermocycling, Augmentin: 1.35 ± 1.13 after drug treatment; 1.43 ± 1.21 after thermocycling, Phenytoin: 1.25 ± 0.50 after drug treatment; 1.08 ± 0.55 after thermocycling, Ivorspan: 1.93 ± 0.92 after drug treatment; 1.27 ± 0.68 after thermocycling, Albuterol: 1.15 ± 0.48 after drug treatment; 1.32 ± 0.92 after thermocycling, Multivitamins: 1.64 ± 0.62 after drug treatment; 1.12 ± 0.52 after thermocycling, and control (distilled water): 0.90 ± 0.42 after thermocycling. Statistically significant differences between the two time points were found only for Ivorspan ($p = 0.05$) and multivitamins ($p < 0.05$).

Table 4. Intragroup Comparison of Color Stability (ΔE) for GIC and Composite Resin Between Post-Drug and Post-Thermocycling Stages.

		After Drug (Mean ± SD)	After Thermocycling (Mean ± SD)	p-value
GIC	**Paracetamol**	1.98 ± 0.93	1.94 ± 0.64	0.895
	Acetaminophen	2.34 ± 1.26	1.27 ± 0.51	0.009*
	Augmentin	2.61 ± 1.35	2.61 ± 1.29	0.992
	Phenytoin	2.45 ± 1.52	2.18 ± 1.38	0.627
	Ivorspan	2.31 ± 0.69	2.17 ± 0.97	0.680
	Albuterol	2.15 ± 0.59	2.16 ± 0.77	0.985
	Multivitamin	6.69 ± 2.48	3.83 ± 1.63	0.002*
	Control	-	2.64 ± 1.1	-
Composite	**Paracetamol**	1.26 ± 0.58	1.38 ± 0.98	0.714
	Acetaminophen	2.15 ± 1.45	1.96 ± 0.89	0.691
	Augmentin	1.35 ± 1.13	1.43 ± 1.21	0.871
	Phenytoin	1.25 ± 0.5	1.08 ± 0.55	0.423
	Ivorspan	1.93 ± 0.92	1.27 ± 0.68	0.050*
	Albuterol	1.15 ± 0.48	1.32 ± 0.92	0.541
	Multivitamin	1.64 ± 0.62	1.12 ± 0.52	0.030*
	Control	-	0.9 ± 0.42	-

**Statistically significant at $p < 0.05$.*

Fig. 2. Mean ± SD of color stability (ΔE) for both restorative materials after drug exposure and thermocycling under different medications.



Statistical Significance:

Statistically significant differences ($p < 0.05$) between post-drug and post-thermocycling color changes were observed for acetaminophen and multivitamins in the GIC group and for Ivorspan and multivitamins in the composite group. These findings indicate that multivitamins induced the most pronounced reduction in discoloration after thermocycling, particularly in the GIC specimens.

Additionally, the type of restorative material significantly influenced ΔE outcomes across medication types, underscoring the importance of material selection in maintaining esthetic stability.

Discussion:

This in vitro study investigated the effects of various pediatric liquid medications on the color stability of two restorative materials commonly used in pediatric dentistry: GIC and composite resin. The findings demonstrated that all tested medications induced detectable color changes (ΔE), with multivitamins and the cough suppressant caused clinically perceptible discoloration. Overall, the composite resin exhibited superior color stability compared to that of GIC.[15]

The differences observed between the two materials are consistent with their inherent physical and chemical properties. GIC, known for its porosity and hydrophilicity, exhibited higher ΔE values for nearly all medications tested. These properties increase its susceptibility to pigment absorption and acid-induced surface degradation. In contrast, the smoother surface texture and less porous, more hydrophobic matrix of the composite resin contributed to its enhanced resistance to staining.[16,17]

These findings were consistent with those of previous studies; Bagheri et al. (2005) and Mehta et al. (2016) who reported that composite resins exposed to acidic sugar-rich syrups exhibited significantly less discoloration than GICs. Similarly, Erdemir et al. (2008) found that nanohybrid composites demonstrated greater color stability, which was attributed to their smaller filler particles, particularly in environments involving dietary or pharmaceutical staining agents.[15,17]

Based on the ΔE_{00} thresholds, the majority of specimens exhibited clinically unacceptable color changes ($\Delta E_{00} \geq 1.8$) following exposure to pediatric medications, with multivitamins producing the most notable effects. Only a few instances, such as the composite specimens in the control group and post-thermocycling multivitamin exposure, demonstrated perceptible but clinically acceptable changes. No materials showed imperceptible color changes. These findings emphasize the susceptibility of restorative materials, particularly GIC, to staining and highlight the importance of material selection in pediatric patients exposed to oral medications.

The most pronounced discoloration in this study was associated with multivitamin syrup (ΔE of 3.83 ± 1.63 in GIC). This result is consistent with the findings of Abushanan et al., who identified multivitamin syrups as potent staining agents, particularly with long-term exposure, leading to visible and progressive color changes in GIC and composite resin.[20] Collectively, these results underscore that frequent exposure to pediatric syrups, especially those characterized by low pH, artificial colorants, and high viscosity, can compromise the esthetic integrity of restorative materials.

Similarly, Augmentin, a commonly prescribed pediatric antibiotic, resulted in clinically visible discoloration, more prominently in GIC. This observation is supported by studies by Almutairi et al. and Dogan and Yıldız, who demonstrated that amoxicillin-based medications led to greater pigment retention in GIC compared to that in composite resins.[18,19] These findings suggest that the acidic pH and synthetic colorants in antibiotic syrups may degrade GIC more severely because of their porous structure and ionic reactivity.

Albuterol, a bronchodilator commonly found in syrups such as Ventolin, also induced significantly greater discoloration in GIC compared to that in composite resin ($p < 0.001$). This outcome is consistent with the work of Almutairi et al., who observed that albuterol syrups—due to their low pH and high sugar content—resulted in increased ΔE values in GIC relative to composite materials [(18)]

The present study also found statistically significant discoloration of GIC following exposure to the antiepileptic medication, phenytoin ($p = 0.012$). Similar results were reported by Dogan & Yıldız, who observed ΔE values as high as 8.6 in GIC and compomers exposed to antiepileptic agents, indicating a strong staining potential over time.[19]

Cough suppressant (e.g., Prospan) and phenytoin also resulted in significant discoloration, reinforcing previous findings by Ravishankar et al. (2011) and Jamal et al. (2022), who identified pediatric medications as major contributors to the esthetic degradation of restorative materials over time.[21] Additionally, Abushanan et al. (2022) reported that both GIC and composite materials immersed in pediatric analgesic syrups exhibited color changes visible to the naked eye, with the degree of discoloration increasing with prolonged exposure.[22]
Nevertheless, the current literature highlighted discrepancies. For instance, Tuncer et al. (2013) found no significant difference in color change between composite resin RMGICs after immersion in pediatric antibiotics, suggesting that certain modern RMGICs may offer improved stain resistance compared to conventional GICs.[23] Moreover, Yesilyurt et al. (2008) reported that composite materials subjected to extended brushing and acidic beverage exposure experience increased surface roughness and color instability, potentially surpassing GIC in long-term discoloration. These findings indicate that the color stability advantage of composites may diminish under mechanical stress such as brushing or abrasion.[24]

Thermocycling is commonly employed in laboratory research to simulate the temperature fluctuations that restorative materials undergo during the consumption of hot and cold foods and beverages, simulating real-life oral conditions. Thermal stresses may cause microcracks and matrix disruption, increasing water absorption and pigment uptake by inducing expansion and contraction of the materials. The inclusion of thermocycling in the present study allowed for a more clinically relevant assessment of the long-term esthetic behavior of restorative materials exposed to pediatric medications.[12,31]

Interestingly, after thermocycling, GIC discoloration did not increase and, in some instances, slightly decreased. This suggests that GIC discoloration primarily occurs during early exposure and that thermal cycling alone does not further intensify pigment absorption once saturation is reached. These observations are consistent with the findings of Mungara et al. (2013), who reported that GIC showed more discoloration than composite when exposed to pediatric medications and that the extent of discoloration was more influenced by the chemical composition of the liquids than by thermocycling itself.[30]

Notably, while most composite groups exhibited reduced ΔE values after thermocycling, specimens exposed to acetaminophen, Augmentin, and albuterol demonstrated slight increases in discoloration. This may result from thermal expansion and contraction disrupting the filler–matrix interface in the composite resins, thereby enhancing water sorption and pigment penetration. The acidic pH and viscous consistency of these drugs may further exacerbate their effect. These findings are consistent with those of Yesilyurt et al. (2008), who observed that thermocycling and chemical exposure increased surface roughness and color instability in resin composites.[31] Conversely, other groups—such as those exposed to multivitamins or the control solution—showed decreased ΔE values, possibly due to pigment saturation or superficial stain removal during thermal cycling.

These results underscore the limitations of GIC in areas with high esthetic demands, particularly in pediatric patients requiring long-term syrup-based medications, and emphasize the importance of implementing surface protection strategies, such as resin coatings or varnishes, to minimize staining susceptibility.

Clinical Implications

Children with chronic conditions often require long-term administration of liquid medications, many of which contain acidic components, sugars, and synthetic dyes. These agents can adversely affect the color stability of restorative materials, particularly GICs. Therefore, when planning restorative treatments for pediatric patients, clinicians should prioritize esthetic longevity in addition to functional requirements.[25]

Because of their superior resistance to discoloration, composite resins may be the preferred material for anterior restorations, where esthetics are of paramount importance. Conversely, RMGICs may serve as a practical alternative for posterior restorations or in situations involving uncooperative children, offering enhanced fluoride release and better esthetic outcomes than conventional GICs.[26]

Dental practitioners should also play an active role in preventive education by advising caregivers to encourage the child to rinse with water immediately after medication intake, reduce the frequency of administering sugary or pigmented syrups when alternatives are available, and consider periodic polishing or the application of surface sealants to help preserve the appearance of esthetic restorations over time.[27]

Research Limitations and Future Directions

Although this study provides valuable insights into the effect of pediatric syrups on restorative materials, it has some limitations. First, the in vitro design could not fully replicate the complexities of the oral environment, including factors such as salivary flow, enzymatic activity, tooth brushing, and dietary variations. Second, the one-week exposure period may not accurately reflect long-term clinical scenarios, especially in children undergoing extended medication regimens.

Therefore, future research should aim to conduct longitudinal in vivo studies involving pediatric patients to simulate clinical conditions with accurate precision,[28,29] evaluate the efficacy of preventive interventions such as polishing or surface coating in mitigating discoloration and expand the range of tested restorative materials and medications to include newer formulations with improved esthetic and mechanical properties.

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