Original Article

Effects of Different Pediatric Drugs and Toothbrushing on Color Change of Restorative Materials Used in Pediatric Dentistry

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Abstract

Objective: The purpose of this study was to evaluate the effects of different pediatric drugs and toothbrushing on color changes of restorative materials used in pediatric dentistry. **Materials and Methods:** Sixty specimens were prepared from each of three restorative materials (compomer [Dyract XP], glass hybrid [Equia Forte], and glass carbomer [GCP Glass Fill]). Specimens were divided into six solution groups (n = 10) and immersed in five different pediatric drugs (antibiotic, analgesic, common cold syrup, cough syrup, and an iron and vitamin formula) and distilled water. Two subgroups (brushed and unbrushed) were established for each group (n = 5). Specimens were agitated for 1 min every 8 h over 2 weeks. Color changes [CIEDE2000 (ΔE_{00})] were calculated at baseline, 7, and 14 days. Data were subjected to 4-factor mixed-design ANOVA using a general linear model procedure for repeated measurements. **Results:** After 14 days, the highest ΔE_{00} was found in the compomer/non-brushing group immersed in iron and vitamin formula (5.6 ± 0.27), and the lowest was in glass hybrid/brushing group immersed in distilled water (0.59 ± 0.8) pairwise. ΔE_{00} values were significantly greater for compomer than for glass hybrid or glass carbomer ($P < 0.05$). There were statistically significant differences between the brushing and non-brushing groups for all tested solutions on the compomer specimens (except antibiotic) and glass hybrid specimens (except antibiotic and cough syrup). The ΔE_{00} values in brushing groups were significantly lower statistically than in non-brushing groups ($P < 0.05$). **Conclusions:** Toothbrushing dramatically affected the color stability of the aesthetic restorative materials. The content of pediatric drugs is also an important factor for color change. Glass hybrids and glass carbomers used with their surface sealants appeared to be more resistant to staining from pediatric drug formulations than compomers.

Keywords: *CIEDE2000, color science, dental materials, pediatric drugs, spectrophotometer*

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Introduction

An aesthetic appearance has ever-increasing importance in today's dentistry practice. Accordingly, the demand for a nice smile is rising among children as well as adults, making it a primary concern for patients. One's appearance is frequently related to social acceptance and professional success, thus having an impact on quality of life.[1,2] Likewise, the restoration of primary teeth is important not only for treating caries but also for the physiological and psychological development of children.

The rise in aesthetic expectations has led to the use of a variety of restorative materials, resulting in an expanding diversity of dental materials used in clinical practice. There are many restorative materials available in pediatric dentistry, including glass ionomer cements (GIC), polyacid-modified composite

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resins (compomers), and composite resins.[3] Glass ionomer restorations are frequently preferred in pediatric dentistry for characteristics such as anti-cariogenic properties, fluoride releasing and recharging abilities, and chemical bonding to the tooth structure. In recent years, new glass ionomer systems have been developed and introduced to the market in response to the disadvantages of conventional glass ionomer materials, including low chemical properties and moisture sensitivity.[4] Examples of these materials are glass hybrids[5] consisting of high-viscosity ionomer materials and glass carbomer (GC) materials,[6] restorative materials based on glass ionomer containing nano-sized hydroxyapatite.

Color stability is an essential parameter used to assess the aesthetic success of restorations.[7] Staining is a significant problem that influences all restorative materials after long-term use, arising from both intrinsic and extrinsic factors.[8] Intrinsic color changes may be related to factors such as resin matrix content and the size and ratio of filler particles.[9] The extrinsic factors of discoloration arise from the adsorption or absorption of colorants, such as those found in colored beverages.[10] The use of pediatric drug formulations has been reported as a significant cause of discoloration in restorative materials.[11]

The main reasons for prescribing pediatric liquid drugs are analgesics, antibiotics, antihistaminic medications, and multivitamins to treat children's chronic requirements. These medications improve and protect the health by means of active ingredients they contain, but they may have undesired side effects from their inactive contents.[12] Thus, it is important to consider the long-term results when using these formulations. In the literature, there are several studies relating to the cariogenicity and erosive potential of pediatric liquid drugs,[13-16] but there are few studies on the effects of pediatric medicines on discoloration of teeth and restorative materials. Pani *et al*.[17] investigated the extrinsic tooth staining potential of high-dose and sustained-release iron syrups on primary teeth, but there is only one study in which the staining effects of pediatric drugs was tested on restorative materials applicable for pediatric dentistry.[11] No study was found that investigated the impact of toothbrushing on the color stability effects of common pediatric drugs.

The present study aimed to analyze the effect of toothbrushing on color changes by measuring the discoloration of three pediatric restorative materials after 1 week and 2 weeks' exposure to different pediatric drugs.

Three null hypotheses were considered: First, that toothbrushing would not mitigate the restorative materials' susceptibility to staining; second, that the type of restorative material would not affect color stability; and third, that exposure to different pediatric drugs and the duration of exposure would not affect the color stability of restorative materials.

Material and Methods

Tables 1 and 2 present the characteristics of the pediatric drugs and restorative materials evaluated in this study.

Specimen preparation

Using a Teflon ring, 60 disk-shaped specimens (10 mm in diameter × 2 mm thick) were obtained from each of the materials. A cellulose acetate matrix strip was placed over the ring, and it was held between two glass slides, with 1 mm thickness to eliminate air entrapment and voids. The manufacturer's instructions were followed in preparing a total of 180 samples of restorative materials. To ensure standardization, A2 color was used in all materials.

The specimens of light-polymerized compomer were polymerized by applying a light-emitting diode (LED) polymerization light (Elipar Free light 2, 1,200 mW/cm^2, 3M ESPE, Ireland) for 20 s to each surface, with the tip of the light on the glass slide (1 mm from the specimen) for 40 s.

A high-viscosity conventional GIC (Equia Forte (EF)) restorative material was applied to each capsule with a 10-s mixer, molded with a carrier, and left at room temperature for 5 min to complete the hardening. The EF coating was applied to the surface of the specimens in accordance with the manufacturer's recommendation and cured for 20 s using the LED unit.

A high-viscosity conventional GIC with nanofluoride/hydroxyapatite (GCP Glass Fill) restorative material was applied to each capsule for 15 s with a mixer, molded with a carrier, and the GCP Gloss surface coating was applied in accordance with the manufacturer's instructions. Curing was performed using GCP CarboLED (1,400 mW/cm^2 (max 60° C), GCP-Dental, Elmshorn, Germany) for 90 s.

After completing the polymerization process, the specimens were polished using aluminum oxide disks (Sof-Lex, 3M ESPE, St. Paul, MN, USA) with an electric handpiece, at 15,000 rpm for 10 s on each disk (coarse, medium, fine, and superfine). All specimens were kept in distilled water at 37°C for 24 h to complete the polymerization process.[18]

Color change measurement and brushing cycles

After polishing, the specimens were rinsed and dried with tissue paper, and baseline color measurements were performed. Specimens were randomly divided into six solution groups (n = 10). Distilled water (pH 6.47) was used as the control solution. Two subgroups (brushed and unbrushed) were established for each group (n = 5). Based on data from a previous study,[19] a minimum sample size of 5 specimens per group was calculated using the G*Power software program (version 3.1.9.2; power 0.95, $\alpha = 0.05$, $\beta = 0.05$).

The spectrophotometer was calibrated with its own calibration instrument, and measuring was performed at the center of each specimen. Whole color measurements were carried out with the CIEDE2000 color system relative to D65 standard illumination against a standard white background using a clinical spectrophotometer (Vita EasyShade Advance 4.0, Ivoclar Vivadent, Liechtenstein). Each specimen's measurement was done three times and the average was used. Specimens were kept in distilled water until assigned to a medication group (5 undiluted pediatric liquids) for 1 min three times a day (at 8 h intervals). This protocol was repeated for 2 weeks. The solutions were replaced daily. The antibiotic was prepared once a week and refrigerated. Specimens were kept in distilled water between immersion periods. The temperatures of all solutions were measured using a thermometer (Flex Temp Smart; Omron, Hoofddorp, The Netherlands) to ensure a standard degree (room temperature). Specimens in the brushing subgroups were brushed using a fluoride-free toothpaste (R.O.C.S Kids Fruity Cone, Tallinn, Estonia) once a day with an electric toothbrush (Braun Oral-B Genius Pro 9000). To simulate home application procedures, 2 ml of toothpaste was applied to the surfaces of tested materials. Each specimen was brushed using 40 strokes with a standardized force of 2 N in "continuous" mode, by the same operator (SY). This number was based on an estimate that a tooth is brushed for 10 s in a daily toothbrushing of 2 min duration.[20] Following brushing, the specimen was rinsed under tap water and returned to distilled water until the next application. Prior to color measurement, any liquid on the specimen was removed, and specimens were lightly rinsed with distilled water and dried with tissue paper.

The color values (L*, c*, h*) of each specimen for each immersion period (1 week and 2 weeks) were measured three times by placing each specimen onto the measuring head of the spectrophotometer. After measuring each specimen three times, the mean values were calculated and recorded. Color changes between baseline and measurements made at 7 and 14 days were calculated. The measurements were performed in accordance with the CIEDE2000 (ΔE_{00}) system. ΔE_{00} was calculated using the following formula[21,22]:

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

Color differences were evaluated ultimately via comparison with 50:50% perceptibility (PT) and 50:50% acceptability (AT) thresholds. The PT (0.81 units) and AT (1.77 units) values for CIEDE2000 (1:1:1) were obtained from a recent study.[23]

Statistical analysis

Descriptive statistics were calculated for each variable and expressed as "mean ± standard error of mean (SEM)." The data were subjected to 4-factor mixed-design ANOVA (analysis of variance) using the general linear model procedure for repeated measurements. The model included "material," "solution," "brushing status," and "time" as the main effects, as well as their interaction terms. Simple-effect analysis with Bonferroni adjustment was used to eliminate any significant interaction of effect terms as post-hoc analysis. Statistical significance was set to $P < 0.05$, unless otherwise noted. SPSS version 14.01 software was used for the statistical analyses.

Results

The mean color differences (ΔE_{00}) and the standard deviations of all groups are presented in Table 3. The data with superscript letters in the table showed statistically significant differences. The highest change was observed in the Floradix–compomer/non-brushing group (5.06 ± 0.3), while the minimum was found in the distilled water–glass hybrid/brushing (0.59 ± 0.08) combination at week 1. For week 2, the maximum ΔE_{00} was again found in Floradix–compomer/

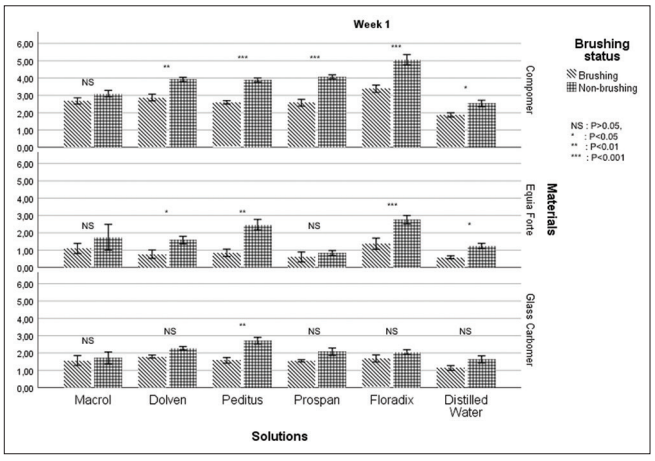

Figure 1: ΔE_{00} values between baseline and 1 week

non-brushing (5.6 ± 0.27), as in week 1, and the minimum was found in the distilled water–glass carbomer/brushing (0.98 ± 0.22) combination.

Figure 1 shows the mean ΔE_{00} values of the three restorative materials after 7 days' exposure to pediatric drugs. There are statistically significant differences between the brushing and non-brushing groups for all the tested solutions in the compomer specimens (except Macrol) and EF specimens (except Macrol and Prospan). The ΔE_{00} values in brushing groups were significantly lower statistically than in non-brushing groups ($P < 0.05$). Among the GCP glass fill specimens, there were no statistically significant differences between the brushing and non-brushing groups in solutions other than Peditus. Among the unbrushed specimens, discoloration in the compomer group was found to be more significant statistically than in the EF and GCP glass fill groups for all staining media tested.

Figure 2 shows the mean ΔE_{00} values after 14 days. Among the compomer specimens, there was a statistically significant difference between brushing and non-brushing

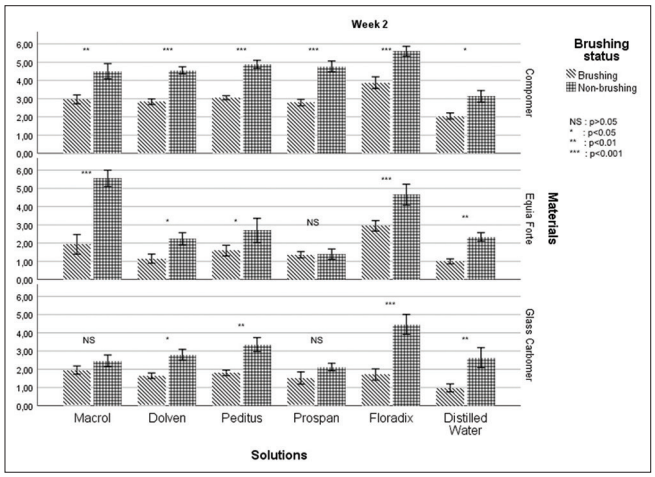

Figure 2: ΔE_{00} values between baseline and 2 weeks

Table 1: Restorative materials used in the present study

Product	Material Type	Mixing	Curing	Manufacturer
Dyract XP	Polyacid modified composite resin	N/A	Light-cure for 20 seconds	Dentsply DeTrey, GmbH, Germany
GCP Glass Fill	Glass carbomer	15 seconds with a mixer	Light-cure for 90 seconds	GCP Dental, Vianen, The Netherlands
Equia Forte	Glass hybrid	10 seconds with a mixer	No cure, allowed to set for 5 minutes	GC Corporation, Tokyo, Japan

Table 2: Pediatric liquid drugs used in this study

Brand Names	Active ingredient	Therapeutic class	pH
Macrol	Clarithromycin	Antibiotic	5.1
Dolven	Ibuprofen	Analgesic	4.3
Peditus	Paracetamol	Common cold syrup	5.7
Prospan	Ivy leaves dry extract	Cough Syrup	4.1
Floradix	Organic iron from ferrous gluconateVitamins B_1, B_2, B_6, B_{12} and C Herbal extracts and fruit juice	Iron and vitamin formula	3.2

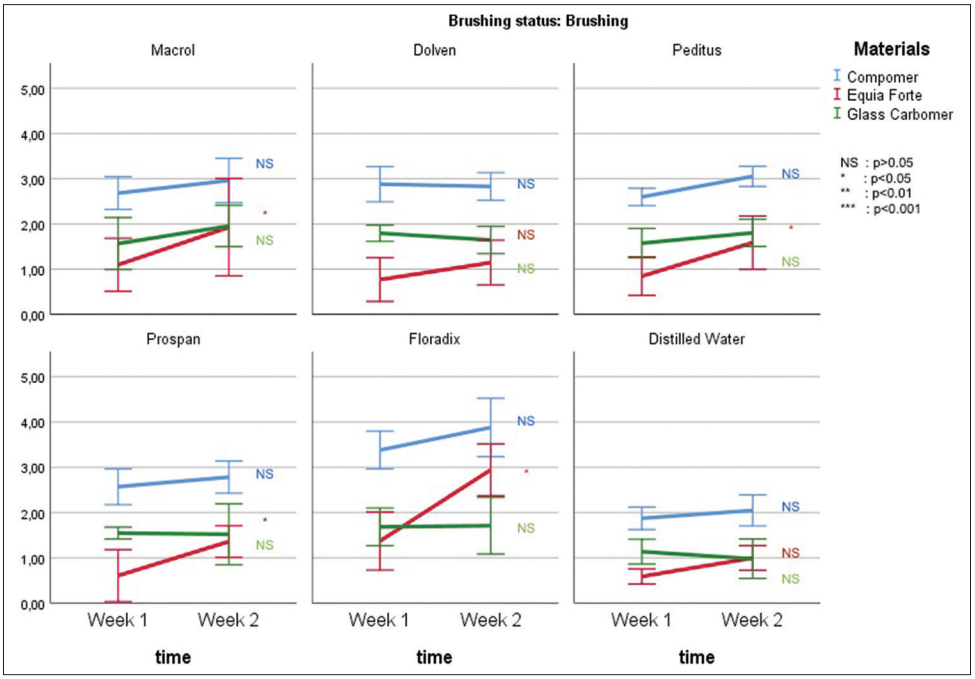

Figure 3: Color changes of restorative materials in solutions with toothbrushing

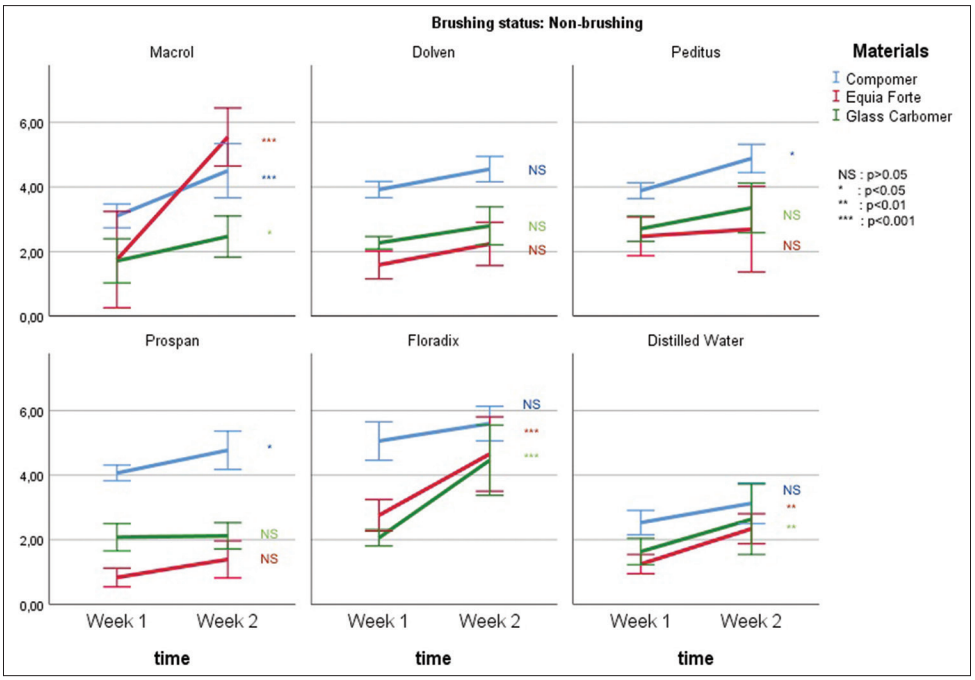

Figure 4: Color changes of restorative materials in solutions without toothbrushing

Table 3: The mean and standard deviations of ΔE_{00} values

		Material					
		Compomer		**Equia Forte**		**GCP Glass Fill**	
		Brushing	**Non-brushing**	**Brushing**	**Non-brushing**	**Brushing**	**Non-brushing**
Time	***Solution***	***Mean±SD***	***Mean±SD***	***Mean±SD***	***Mean±SD***	***Mean±SD***	***Mean±SD***
Week 1	Macrol	2.68 ± 0.18^{X}	$3.1\pm0.18^{ac,x}$	1.1 ± 0.29^{Y}	$1.75\pm0.75^{ac,y}$	1.57 ± 0.29^{Y}	1.71 ± 0.34^{y}
	Dolven	$2.88\pm0.2^{a,X,A}$	$3.92\pm0.13^{a,x,B}$	$0.77\pm0.24^{Y,A}$	$1.58\pm0.22^{ac,y,B}$	$1.79\pm0.09^{Z,A}$	$2.27\pm0.1^{y,A}$
	Peditus	$2.6\pm0.1^{X,A}$	$3.89\pm0.12^{a,x,B}$	$0.85\pm0.21^{Y,A}$	$2.47\pm0.3^{ab,y,B}$	$1.57\pm0.16^{Y,A}$	$2.71\pm0.2^{a,y,B}$
	Prospan	$2.57\pm0.2^{X,A}$	$4.07\pm0.12^{ab,x,B}$	$0.6\pm0.29^{Y,A}$	$0.83\pm0.14^{c,y,A}$	$1.55\pm0.07^{Z,A}$	$2.08\pm0.21^{z,A}$
	Floradix	$3.38\pm0.2^{a,X,A}$	$5.06\pm0.3^{b,x,B}$	$1.37\pm0.32^{Y,A}$	$2.76\pm0.24^{b,y,B}$	$1.68\pm0.21^{Y,A}$	$2.06\pm0.13^{y,A}$
	Water	$1.87\pm0.12^{b,X,A}$	$2.53\pm0.19^{c,x,B}$	$0.59\pm0.08^{Y,A}$	$1.24\pm0.15^{c,y,B}$	$1.13\pm0.14^{XY,A}$	$1.63\pm0.2^{b,y,A}$
Week 2	Macrol	$2.96\pm0.24^{X,A}$	$4.5\pm0.42^{ab,x,B}$	$1.93\pm0.54^{ab,X,A}$	$5.55\pm0.45^{a,x,B}$	$1.95\pm0.23^{X,A}$	$2.46\pm0.32^{b,y,A}$
	Dolven	$2.83\pm0.15^{X,A}$	$4.55\pm0.2^{a,x,B}$	$1.14\pm0.25^{b,Y,A}$	$2.23\pm0.34^{b,y,B}$	$1.64\pm0.15^{Y,A}$	$2.79\pm0.29^{b,y,B}$
	Peditus	$3.05\pm0.11^{X,A}$	$4.88\pm0.22^{a,x,B}$	$1.59\pm0.29^{ab,Y,A}$	$2.69\pm0.66^{b,y,B}$	$1.8\pm0.15^{Y,A}$	$3.35\pm0.38^{ab,y,B}$
	Prospan	$2.78\pm0.18^{X,A}$	$4.77\pm0.3^{a,x,B}$	$1.36\pm0.17^{b,Y,A}$	$1.39\pm0.29^{b,y,A}$	$1.52\pm0.34^{Y,A}$	$2.12\pm0.2^{b,y,A}$
	Floradix	$3.88\pm0.32^{a,X,A}$	$5.6\pm0.27^{a,x,B}$	$2.94\pm0.29^{a,X,A}$	$4.65\pm0.58^{a,xy,B}$	$1.71\pm0.31^{Y,A}$	$4.46\pm0.54^{a,y,B}$
	Water	$2.05\pm0.17^{b,X,A}$	$3.13\pm0.31^{b,x,B}$	$1\pm0.14^{b,X,A}$	$2.34\pm0.23^{b,x,B}$	$0.98\pm0.22^{X,A}$	$2.63\pm0.55^{b,x,B}$

[a, b, c]: Values in the same column with different superscripts show the statistical differences between solutions within each material, brushing status, and time. [X, Y, Z]: Values in the same row with different superscripts show the statistical difference between materials for only brushed items within each solution and time. [x, y, z]: Values in the same row with different superscripts show the statistical difference between materials for only unbrushed items within each solution and time. [A, B]: Values in the same row with different superscripts show the statistical difference between brushing and non-brushing within each solution, material, and time

groups in all specimens ($P < 0.05$). There were statistically significant differences between brushing and non-brushing subgroups in all solutions except Prospan in EF specimens, and Prospan and Macrol in GCP glass fill specimens ($P < 0.05$).

Figure 3 illustrates color changes of brushed specimens exposed to all pediatric drugs and distilled water over time. There were no statistically significant differences between week 1 and week 2 in ΔE_{00} values for all solutions in the brushing group of compomer and GCP glass fill specimens. However, there was a statistically significant difference between week 1 and week 2's ΔE_{00} values in the brushing group of EF specimens (except in Dolven and distilled water solutions).

Figure 4 illustrates color changes of unbrushed specimens exposed to all pediatric drugs and distilled

water over time. Statistically significant differences were observed between baseline color measurements and those taken after 2 weeks for Macrol solution and all restorative materials tested ($P < 0.05$). For Dolven solution, no statistically significant difference was observed in the non-brushing groups of all restorative materials. There were statistically significant differences between ΔE_{00} values of only the non-brushing groups of Peditus and Prospan solutions. In Floradix and distilled water solutions, no statistically significant difference was observed in non-brushing compomer, whereas statistically significant differences were observed between the EF and GCP glass fill specimens.

Evaluating the rate of color change for all solutions and restorative materials in all examination periods, it was determined that, for some groups, the ΔE_{00} values were lower than 1.8 [50:50% acceptability threshold value for CIEDE2000 (1:1:1) obtained in a recent study carried out by Paravina *et al*.].[23] In week 1, the EF and GCP glass fill brushing groups showed acceptable color change values for all solutions. The same acceptable values were also observed in week 2, except in Macrol and Floradix. The compomer did not yield acceptable values in any group.

Discussion

In the present study, the impact of toothbrushing was evaluated on the color stability of two high-viscosity glass ionomer restorative materials and compomers, after 1 week and 2 weeks' exposure to common pediatric drugs. According to these results, the first null hypothesis of the study was partially rejected: significant differences were found among the brushing and non-brushing subgroups for all tested pediatric medicines in the compomer specimens, EF specimens (except Prospan), and GCP glass fill specimens (except Prospan and Macrol). Because color changes differed among the restorative materials used in the study according to the pediatric drugs tested, the second null hypothesis was rejected. Furthermore, color change over time was different for each pediatric drug tested, thus the third null hypothesis was partially rejected.

The CIELAB color difference system is most commonly used in dentistry, but since 2001, the International Commission on Illumination (CIE) has been recommending the use of a new color difference formula, CIEDE2000 (ΔE_{00}), that utilizes the concepts of chroma and hue, reinforcing the importance of the original concepts proposed by Munsell.[24] In 2013, this formula was accepted as the standard for detecting color differences. In this formula, the number of parameters used was increased, and calculations became more complicated when compared to the CIELAB formula. Since color perception varies according to backgrounds with different brightness levels, this change in color perception was incorporated into the formula. The previous formula basically measured the distance between two points in the space, whereas the addition of S_L to the formula of CIE2000 had the effect of including brightness in the calculation and seems to offer improvements over the CIELAB formula, implying better clinical relevance.[25] Therefore, in the present study, ΔE_{00} was used to assess the color stability of restorative materials.

The detection of color change is based mainly on visibly perceptible changes in color values of an object and assessing the amount of color change that affects the aesthetic appearance.[26] Perceptibility threshold (PT) and acceptability threshold (AT) define the extent of differences and serve as a control to assess the success of dental materials and to interpret visual and instrumental findings, as reported by Paravina *et al*.[23] A color change value that can be visually perceived by 50% of the observers is defined as 50:50% PT. The color change value that is clinically acceptable for 50% of observers is defined as 50:50% AT.[23,26] Consequently, an acceptable match in dentistry is a color difference at or below the AT. CIEDE2000 reported 50:50% AT as 1.8 ΔE_{00}, meaning that $\Delta E_{00} > 1.8$ values are considered clinically unacceptable color changes.[23] When the rate of color changes was investigated for all solutions and restorative materials for all examination periods, ΔE_{00} values were lower than 1.8 for EF and GCP Glass Fill specimens. The EF and GCP Glass Fill specimens in the brushing subgroup at 1 week showed acceptable color change values for all solutions. The same acceptable values were found in the second week, except in Macrol and Floradix. The compomer did not reach acceptable values in any group.

In previous studies it was reported that glass ionomer cements were the material most resistant to staining due to their higher water content.[27,28] Similarly, Tüzüner *et al*.[11] reported that EF yielded acceptable color stabilities when compared to the composite or compomer, including for all tested pediatric drugs. The higher color change of compomer may be correlated with its higher resin content. It was reported that the color change of resin-containing restorative materials is related to the structure of the resin matrix and water sorption, and that the water establishes the relationship between colorant pigments and resin matrix.[27] GCP glass fill materials were shown to be resistant to water. It is thought that the low level of color change of GCP glass fill restorative material is related to the low levels of water sorption

and water solubility.[29] Given the results obtained here, it can be stated that the second null hypothesis must be rejected, because not all materials showed the same color stability. In this aspect, compomers yielded the least color stability; this result can be explained by the material's composition, as it includes hydrophilic resins, such as Bis-GMA and HEMA, and carboxyl groups, causing increased water affinity.[10,30]

The syrups used in the present study were preferred, because they are among the most frequently prescribed medications, according to data obtained from the Turkish Medicines and Medical Devices Agency. The protocol employed in the present study is based on a syrup ingestion frequency of 3 times a day for 1 min (10 ml in each) under agitation of the solution during specimen immersion. The agitation was applied because some authors have reported that the agitation occurring when a substance is ingested increases the substance's erosive capacity.[31] In the present study, the 14-day experimental period was preferred in order to assess the long-term effect.

Many pediatric liquid medications are characterized by high sugar content, high titratable acidity, and low pH. Given these characteristics, the possible relationship between dental caries and erosion with the intake of liquid oral medications was questioned in many studies.[32-34] Moreover, besides possible dental erosion and caries, the use of such medications also causes a decrease in the color stability of teeth and restoration materials. It was reported that the extrinsic color change in deciduous teeth may negatively affect the social development of children in the pre-school period.[35] Other problems may arise as well, such as increased frequency of dental visits due to the need to replace restorations, increased cost of replacing restorations, and worsening behavior management/dental anxiety.[12,14-16] Since dental treatments are costly and time-consuming processes, they should ideally last a long time. The crucial step in overcoming problems associated with exposure to medications is toothbrushing. The results of the present study revealed significant differences after 14 days of brushing versus non-brushing on EF (except Prospan), GCP glass fill (except Prospan and Macrol), and compomer exposed to the pediatric drugs tested. ΔE_{00} was found to be consistently lower in brushing groups. Parallel with our results, Bezgin *et al*.[19] concluded that regular brushing influenced significantly the color stability of aesthetic restorative materials and decreased the amount of color change over time. In their study examining the effects of different beverages on color changes of various restorative materials, they brushed each specimen once a day with a children's toothpaste containing fluoride. Fluoride particles are known to have adverse effects on the resin matrix of the materials and on the monomer content in the resin matrix,[36] so we preferred to use a fluoride-free, low abrasive (RDA: 59) toothpaste suitable for 3- to 7-year-old children.

Besides toothbrushing, color stability is also affected by the formulations, pH, and other characteristics of the medications used. In the present study, the highest ΔE_{00} value was observed in the non-brushing group of Floradix–compomer in week 2. In a similar study carried out by Tüzüner *et al*.,[11] the maximum color change was observed in Ferrosanol B–composite group. Both are liquid medications containing ferrous and vitamin. Since Ferrosanol contains sugar and artificial sweetener, the use of herbal drugs has become more popular. Floradix liquid contains vitamins B_1, B_2, B_6, B_{12}, C, and iron from ferrous gluconate, which is a particularly absorbable form. It contains no alcohol, preservatives, colorants, or artificial sweetener. For this reason, in the present study, a herbal medication was used as the ferrous substance. In all the non-brushing Floradix groups, the acceptability threshold was exceeded. In the brushing Floradix–composite group, however, the ΔE_{00} was higher than the acceptability threshold, but the brushing Floradix–GCP glass fill and EF groups yielded acceptable values. In the Floradix group, the minimum ΔE_{00} value was observed in the EF brushing group in week 1 (1.37). Both GCP glass fill and EF are restorative materials used with a surface sealant. GCP gloss is monomer-free and consists of modified polysiloxanes, whereas the EF coating consists of methacrylic monomers that can be polymerized (according to the manufacturer's claim) and thus assures better isolation and protection from exposure to moisture.[37] Surface sealants can be used to minimize the color change in compomer fillings also. Surface sealants are used to saturate the material surface, as well as to correct any defects, voids, and/or irregularities, increasing wear- and stain-resistance, and thus enhancing the aesthetic qualities.[38-40]

Tupalli *et al*.[15] investigated the erosion potential of various pediatric liquid medications on deciduous teeth using SEM, and reported that all the medications tested showed erosive effects. Neamat *et al*.[41] stated that the resin matrix is softened due to the low pH levels of potentially colorant beverages, and the chemical erosion occurring as a result of this process negatively influences the integrity of the tooth-colored restorations' surfaces. This degradation may cause a higher level of water absorption, with accompanying discoloration. Our

findings showed that the pH of the studied medications ranged between 3.2 and 5.7, with iron and vitamin formula followed by cough syrup having the lowest pH values. Prospan is an herbal cough syrup whose active ingredient is ivy leaf extract. It is alcohol-free, sugar-free, and contains no coloring. Although its pH was low, the EF–brushing group immersed in Prospan yielded the lowest ΔE_{00} value among all the drugs, except distilled water. After 14 days, no significant differences were observed between brushing and non-brushing groups for EF and GCP glass fill immersed in Prospan. Moreover, EF specimens in the non-brushing subgroup at both 1 and 2 weeks showed acceptable color change values for Prospan. Similarly, Imparato *et al*.[42] found that pH variations do not increase color changes of fluoride-releasing dental materials. Results showed that color change of restorative materials is a multifactorial phenomenon, and that a range of factors, including the composition of the pediatric drugs, colorant penetration, pH, toothbrushing, and type of restorative materials may all contribute to the amount of staining observed.

Most medications contain sucrose and citric acid. Changing the type of acid (i.e. using maleic acid instead of citric acid) has proven to be less cariogenic. It is posited that using sweeteners such as Xylitol or Sorbitol may decrease the erosive and cariogenic effects of the medications. Negative consequences, such as color change in teeth and in restorative materials, may be prevented by modifying the contents of medications. Pharmaceutical companies should indicate the type and amount of sweetener added and the negative effects on teeth. In fact, medications containing no cariogenic substances should be introduced on the market and incorporate a "Teeth-Friendly" symbol on the package.[15]

Certain limitations of the present study should be taken into consideration when interpreting our results. In the oral environment, restorative materials are constantly exposed to coloring ingredients from food and beverages, and they are immersed in saliva. This study attempted to mimic the oral environment, and toothbrushing was performed with dentifrice diluted in distilled water. Clinically, this dilution occurs in saliva, whose special properties include the presence of enzymes, specific proteins, and ions that may diminish the effect of toothbrush abrasiveness on the samples. This may affect the color stability of restorative materials. Further studies need to be supported by *in vitro* study designs investigating the effect of the chemical and physical properties of pediatric medicines on restorative materials and enamel topography.

Conclusions

- Compomers yielded significant discoloration values when exposed to commonly used pediatric drugs.
- EF and GCP glass fill seem to be more resistant to the staining effects of pediatric drug formulations.
- Toothbrushing significantly improved the color stability of aesthetic restorative materials.
- The content of pediatric drugs is important to color change. The discoloration effect of drug solutions on restorative materials depends on the composition of the material, the types of pigment found in the solutions, and exposure time.
- Further studies should be supported with *in vivo* study designs to evaluate the effects of commonly used drugs on restorative materials used in pediatric dentistry.

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Conflicts of interest

There are no conflicts of interest.

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