

Original Article

An experimental study on the effect of four pediatric drug types on color stability in different tooth-colored restorative materials

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ABSTRACT

Background: One of the drawbacks of tooth-colored dental restorations is their discoloration over time. The present study aimed to determine the effect of four categories of pediatric medications, including analgesics, antibiotics, anticonvulsants, and multivitamins, on two types of tooth-colored dental materials, namely, composite resins and glass ionomer cements.

Materials and Methods: In this *in vitro* study, a total of 40 specimens with disc shapes (with a diameter of 5 mm and thickness of 2 mm) were prepared from each material and immersed in eight different drugs for 2 min three times a day for 1 week. The values of the baseline color were calculated based on the CIE (International Commission on Illumination) L*a*b* system. After 7 days, ΔE values were calculated. Two-way analysis of variance was employed for statistical analysis. Statistical significance was defined at 0.05.

Results: Statistical analysis showed that there were significant differences between ΔE and different restorative materials as well as ΔE and drug types ($P < 0.001$).

Conclusion: According to the results of this *in vitro* study, all the four types of drugs caused the discoloration in all the restorative materials, and the color change values were affected by the type of used drug and restorative material.

Key Words: Antibiotic dental restorations, discoloration, spectrophotometry

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INTRODUCTION

Color stability is an important requirement affecting the choice of restorative materials. At present, esthetic appearance is desired by both children and parents. To meet this increased esthetic demand, various compositions of restorative materials have been developed for clinical use. The most common tooth-colored restorative materials used in pediatric dentistry include composite resins, glass ionomer cements (GIC), and compomers.^[1]

Several advantages, including physicochemical adhesion to tooth tissues, fluoride release, anticaries properties on restoration edges, thermal expansion coefficient similar to that of the natural tooth tissue, and elevated remineralization in adjacent proximal caries, are reported for GIC.^[2,3] Nevertheless, conventional types of GIC suffer from drawbacks including limited fracture/abrasion resistance, poor esthetic features, and moisture sensitivity, weakening

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the physical properties of a material.^[4] As a result, a novel restorative material has been recently developed (Equia, GC, Tokyo, Japan).

Equia contains an extremely viscous type of GIC (EQUIA Fil, previously known as Fuji IX GP Extra) covered with a newly developed nanofilled coating material (Equia Coat, formerly known as G-Coat Plus). The developed material was fortified through alternating the powder/liquid ratio, particle size, and distribution. Equia was developed for application in permanent restoration belonging to Class I, II, and V cavities.^[5] In general, various extrinsic and intrinsic elements cause the discoloration of restorations after a long period.^[6] Factors affecting the discoloration of materials include insufficient polymerization, filler dimension and content, exposure to various foods and beverages, and oral hygiene.^[7-10]

Liquid oral medicines are usually recommended to treat chronic diseases for prolonged periods.^[11] The ingredients used in these liquid formulations include sugars, acids, buffering agents, permitted coloring agents in the form of oil, and/or water-soluble agents.^[12,13] Low endogenous pH and high titrable acidity of these medicines may pose unfavorable effects such as surface degradation of restorations.^[14] With this background in mind, the current study aimed to compare the staining potential of pediatric drugs using an *in vitro* staining model.

MATERIALS AND METHODS

Specimen preparation

The present *in vitro* study was approved by the Research Ethics Committee of Ardabil University of Medical Sciences, Ardabil, Iran (with the ethics code of IR.ARUMS.REC.1396.246). Four groups of drugs commonly consumed by children were tested in the present study [Table 1]. A2 color shades of four restorative materials were selected in this study [Table 2].

A total of 160 samples with disc shapes were fabricated using each material (with a diameter of 5 mm and thickness of 2 mm) according to the manufacturer's instructions using plastic molds. A light cure was applied on the top and bottom surfaces of each specimen for 20 s using a light-emitting diode light-curing unit. All the discs with voids or irregularities in shape or surface were excluded from the study. The specimens were randomly classified into four groups ($n = 40$; from

Table 1: Used staining drugs in the present study

Group	Generic name
Analgesics	Acetaminophen
	Ibuprofen
Antibiotics	Amoxicillin
	Cephalexin
Anticonvulsant	Phenytoin
	Sodium valproate
Multivitamins	Multivitamins
	Vitane, adokid

Table 2: Names and manufacturers of the tested restorative materials

Product	Manufacturer
EQUIA Fil conventional reinforced GIC	GC corporation, Tokyo, Japan
Resin reinforced GIC	GC corporation, Tokyo, Japan
Filtek Z350 XT flowable composite resin	3M ESPE, St.Paul, MN, USA
Filtek Z250 XT composite resin	3M ESPE, St.Paul, MN, USA

GIC: Glass ionomer cement

each material). After the removal of the specimens from the molds and provision of smooth surfaces using Mylar strips, the samples were maintained in distilled water at 37°C for 24 h for rehydration and completion of their polymerization.

Staining process

The samples ($n = 5$) were randomly selected from each material and immersed in each of the eight drug liquids three times/day for 2 min at 37°C within a test period of 7 days. All the solutions were renewed on a daily basis. The specimens were kept in artificial saliva (Glandosan®, Helvepharm AG, Frauenfeld, Switzerland) between the immersion periods.

Color change measurement

The restorative materials' baseline color was measured using a digital spectrophotometer (Vita Easyshade, Vita Zahnfabrik, Bad Säckingen, Germany). Before the measurement of the specimens' color, the device was calibrated with the use of its calibration block based on the manufacturer's instructions. Following the completion of the immersion time, the specimens' color was calculated using the spectrophotometer as previously described. Changes in each specimen's color were investigated according to color specifications with the use of the CIE L*a*b* color space system.

A three-dimensional color space containing lightness (L), red-green (a), and yellow-blue (b)

components are represented by the CIE $L^*a^*b^*$ system. The color variation (ΔE) was measured 1 week after storage and at baseline as two color positions with the use of the following formula:

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

Where ΔL^* is the difference between the L^* values; Δa^* is the difference between the a^* values; and Δb^* is the difference between the b^* values.

Statistical analysis

The Kolmogorov–Smirnov test was utilized to assess the normal distribution of the collected data. Two-way analysis of variance (ANOVA) was employed to assess the type of material and effect of the staining agent on color change. The SPSS software (version 23; SPSS, Chicago, Ill., USA) was used for data analysis.

RESULTS

Table 3 tabulates the mean and standard deviation of ΔE for each material. The mean color changes (ΔE) varied within the range of averaged 3–9.7 for the entire drugs and restorative materials. The most and the least prominent alterations were detected in Vitane-resin modified GIC and Vitane-Filtek Z250 XT, respectively.

The maximum and minimum ΔE^* values were observed for sodium valproate and cephalixin in EQUIA Fil conventional reinforced GIC, respectively. Significantly higher and lower ΔE^* values were reported for vitane and ibuprofen in resin-reinforced GIC, respectively. Cephalixin and vitane induced the maximum and minimum ΔE^* values in Filtek Z250 XT, respectively. In Filtek Z350 XT, the maximum and minimum ΔE^* values were observed for cephalixin and acetaminophen, respectively [Table 3].

As the results of two-way ANOVA demonstrated, the interactions between all the materials and staining drugs were significant ($P < 0.001$). The Games-Howell *posthoc* test was utilized to analyze restorative materials and drugs used in the present study. Subgroup analysis also confirmed significant differences between ΔE and different restorative materials as well as ΔE and drug types ($P < 0.001$). However, no significant difference was detected between the color change values of various drugs in the materials [Tables 4 and 5].

DISCUSSION

Since oral restorations are persistently exposed to staining foods and beverages, the color durability of tooth-colored dental materials is a crucial element. The replacement of the discolored restoration, especially in pediatric patients, is associated with increased costs and time of parents as well as behavior management problems in children.^[14] For the purpose of submitting the entire materials to the same staining protocol without any probable bias, the present *in vitro* study was conducted under standardized staining conditions. This process enabled full control of all the variables. In addition, it does not expose children to superfluous drug prescriptions.

To the best of our knowledge, there have only been a limited number of studies on the effect of drugs on dental materials in children. Therefore, the present study attempted to assess the impact of four pediatric medication types on color stability in various tooth-colored restorative materials. For the prevention of bias resulting from polishing and simulating the most extreme but clinically related situation, the surface did not undergo polishing, and surface smoothness was provided by Mylar strips.

Table 3: Mean and standard deviation of ΔE values of tested restorative materials with pediatric drugs

Drugs	EQUIA Fil conventional GIC		Resin reinforced GIC		Filtek z350 XT		Filtek z250 XT		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Acetaminophen	6.663	0.04	7.482	0.36	3.450	0.27	3.832	0.62	5.315	1.87
Ibuprofen	5.516	0.35	3.910	0.54	4.540	0.29	4.180	0.35	4.536	0.72
Amoxicillin	5.492	0.06	7.652	0.31	6.032	0.52	3.766	0.52	5.748	1.51
Cephalixin	4.113	0.02	8.734	0.48	7.076	0.09	6.410	0.54	6.830	1.70
Phenytoin	5.2367	0.03	7.042	0.79	4.906	0.53	3.950	0.67	5.288	1.34
Valproate sodium	6.760	0.42	6.300	0.46	4.356	0.34	4.878	0.76	5.511	1.11
Adokid	5.988	0.24	4.694	0.55	4.806	0.38	5.796	0.71	5.321	0.75
Vitane	5.805	0.23	9.706	0.40	4.376	0.54	3.090	0.06	6.052	2.61
Total	5.7352	0.76	6.940	1.89	4.867	1.02	4.561	1.17	5.539	1.61

GIC: Glass ionomer cement; SD: Standard deviation

Table 4: Results of Games-Howell *post hoc* test for restorative materials

Restorative material (I)	Restorative material (J)	Mean difference (I-J)	P
EQUIA Fil conventional GIC	Resin-reinforced GIC	-1.2048	0.003
	Filtek Z350 XT	0.8673	0.001
	Filtek Z250 XT	1.1738	>0.001
Resin-reinforced GIC	Filtek Z350 XT	2.0722	>0.001
	Filtek Z250 XT	2.3787	>0.001
Filtek Z350 XT	Filtek Z250 XT	0.3065	0.623

GIC: Glass ionomer cement

Table 5: Results of Games-Howell *post hoc* test for drugs

Drugs (I)	Drugs (J)	Mean difference (I-J)	SE	Significance
Acetaminophen	Ibuprofen	0.7788	0.48221	0.737
	Amoxicillin	-0.4331	0.57137	0.994
	Cephalexin	-1.5153	0.62256	0.261
	Phenytoin	0.0264	0.55349	1.000
	Valpervat sodiom	-0.1958	0.52108	1.000
	Adokid	-0.0057	0.48439	1.000
	Vitane	-0.7376	0.78009	0.978
Ibuprofen	Amoxicillin	-1.2119	0.38228	0.065
	Cephalexin	-2.2941	0.45525	0.001
	Phenytoin	-0.7524	0.35500	0.430
	Valpervat sodiom	-0.9746	0.30199	0.053
	Adokid	-0.7845	0.23303	0.034
	Vitane	-1.5164	0.65438	0.336
Amoxicillin	Cephalexin	-1.0822	0.54880	0.516
	Phenytoin	0.4595	0.46900	0.974
	Valpervat sodiom	0.2374	0.43027	0.999
	Adokid	0.4274	0.38501	0.949
	Vitane	-0.3045	0.72260	1.000
Cephalexin	Phenytoin	1.5417	0.53016	0.108
	Valpervat sodiom	1.3196	0.49623	0.182
	Adokid	1.5096	0.45755	0.059
	Vitane	0.7777	0.76371	0.968
Phenytoin	Valpervat sodiom	-0.2222	0.40623	0.999
	Adokid	-0.0321	0.35795	1.000
	Vitane	-0.7641	0.70855	0.955
Valpervat sodiom	Adokid	0.1901	0.30545	0.998
	Vitane	-0.5419	0.68353	0.992
Adokid	Vitane	-0.7319	0.65598	0.945

SE: Standard error

In the present study, the color measurement was calculated with CIE Lab because it is a repeatable method and sensitive for small color changes similar to the method used in the abovementioned studies.^[15] Based on the human eye's capability in differentiating color, variations in color values were distinguished using three different intervals, including $\Delta E < 1$ undetectable with the human eye, $1.0 < \Delta E < 3.3$ distinguishable by a skilled individual, and $\Delta E > 3.3$ easily observable with naked eyes. The ΔE value of 3.3 or below is clinically regarded as acceptable in dentistry.^[16] According to the results of the current study, the ΔE in all groups was higher than 3.3.

The color stability of esthetic restorative material is relevant to resin matrix hydrophilicity, filler particle dimensions, polymerization depth, and surface properties.^[17-19] Materials with less filler and rough surface are more prone to discoloration.^[20] An increase in particle size causes increased water absorption through polymer chains.^[18]

In the present study, GIC showed a greater color change, compared to composite resin in all the immersion drugs. The relative susceptibility of GIC for staining could be attributed to the porosity of the glass particles, dehydration after setting and drying,

and microcracks allowing staining and discoloration of the restoration. In addition, the glass filler particles can absorb water onto the surface rather into the bulk of the material;^[21] however, based on the literature, hydrophobic substances, such as resin composites, are claimed to have higher color stability and stain resistance, compared to hydrophilic substances, such as GICs and compomers.^[22] The results of the current study also supported the aforementioned conclusion.

Resin-modified glass ionomer (RMGI) showed a greater color change in comparison to other restorative materials in all the immersion drugs. The RMGI and conventional GIC both have a similar ion-releasing glass; nevertheless, smaller filler particles were utilized in RMGI. The light triggers the primary setting reaction subsequently undergoing an acid-base reaction after water absorption.^[23] According to the evidence, during the polymerization of RMGI, the color of glass change and water absorption affected by resin content and HEMA copolymers in this material can cause water absorption up to about 80% of weight.^[20,24]

Equia Forte Fil is offered in the form of encapsulation, simplifying material transportation to the cavity without the need for manual mixing. In this study, Equia Forte Fil demonstrated lower discoloration in comparison to RMGI. The reason might be the nanofilled coating of resin, enabling an enhanced initial filling material stabilization in the curing stage as well as elevated infiltration and closure in GIC superficial defects.

Tüzüner *et al.* studied the effects of pediatric drugs on color stability in different restorative materials among children. They reported significant discoloration values in composites in comparison to those of GIC and compomers. The results of the aforementioned study showed no interaction between restorative materials and drugs which is contrary to the findings of the current study.^[25] This can be due to the ingredients of the materials and surface texture differences. In another study, Afzali assessed the effect of ingested liquids on the color change of composite resin; unlike the present investigation, they concluded that the discoloration values did not depend on the type of staining solution.^[26]

Nanohybrid composite resins are potential alternatives to conventional composite due to better strength, gloss, and lower shrinkage.^[27] Filtek Z350XT Flowable composite resin containing nanofillers

showed higher discoloration in comparison to Filtek Z250 XT composite resin. The color change of composite resins depends on their surface topography, size, and amount of filler particles, water sorption, and hydrophilic nature of their resin matrix.^[28] The higher stainability of Z350XT can be due to its high monomer content, lower filler, and orientation of filler particles.

The results of a study carried out by Khatri and Nandlal revealed that an examined conventional composite resin had higher susceptibility to color change within various media over an extended period in comparison to nanocomposites.^[10] Elwardani *et al.* reported that Filtek Z250 and Filtek Supreme showed no significant difference in surface roughness and color change at all measurement times. Immersion solution had a significant effect on surface roughness and color change.^[29]

In another study, Yazici *et al.* indicated that nanocomposites (Filtek Supreme) have greater color changes than microhybrid composites (Clearfil AP-X) 30 days after dipping in tea.^[30] Adusumilli *et al.* evaluated the color stability of conventional GIC and giomer when immersed in various consumable drinks and foods at different immersion periods and observed conventional GIC demonstrating greater ΔE values, compared to giomer.^[31]

The present *in vitro* study did not mimic the real oral environmental conditions and multiple factors affecting discoloration which is considered a limitation. However, it is recommended to perform further studies for the evaluation of surface irregularities, degree of polymerization, and water sorption, finishing, and polishing of these restorative materials. Furthermore, a study should be carried out on the role of different staining properties of examined pediatric drugs in stabilizing the color of restorative dental materials, probably in terms of sugar contents and pH levels.

CONCLUSION

Despite the limitations of the current study, color changes were observed in all restorative materials after immersion in drugs. In addition, GIC had a greater color change in comparison to nanohybrid composite resins.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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