



THE EFFECT OF COATING MATERIAL ON THE COLOR STABILITY OF GLASS-IONOMER-BASED RESTORATIVE MATERIALS: AN *IN-VITRO* STUDY

ABSTRACT


Objectives: The aim of this study was to determine the effect of coating on the color stability of different glass ionomer cements (GICs) after immersed in different children beverages.

Materials and Methods: Four different GIC and a glass-ionomer coating material were used in this study. Disc shaped sixteen specimens of each GICs were done and divided into two groups, uncoated and coated (n=8). For color change, the specimens were immersed 7 day in the four solutions of cola, orange juice, chocolate milk and water. The color measurements were carried out before immersed solutions and at the end of the 1st and 7th days, using a spectrophotometer. The color change ΔE_{00} was calculated using the CIEDE2000 formula. Data were analyzed by Kruskal-Wallis and Wilcoxon test ($p < 0.05$).

Results: The ΔE_{00} values for all coated and uncoated GICs showed an increase in all solutions after 7 days of immersion. All the ΔE_{00} values obtained from all the specimens immersed in cola were higher than the acceptability threshold. There was no statistical difference in terms of ΔE_{00} values between the coated and uncoated specimens of the same GICs at same time periods.

Conclusions: Coating of GICs exhibited relatively good color stability and protect from the discoloration. The staining effect of GICs should be carefully considered when selecting dental materials in pediatric dentistry.

Keywords: Surface coating agent, glass-ionomer cement, staining.

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INTRODUCTION

The glass ionomer cements (GICs), compomers, and composites are commonly used restorative materials in the paediatric dentistry.^{1,2} Besides the treatment necessities, these dental materials are also preferred for their esthetics.³ Their esthetically pleasing results, anti-cariogenic potentials depending on fluoride release, biocompatibilities, and chemical bonding to dental tissues made GICs a more qualified material group when compared to other restorative materials.⁴ Besides that, GICs also have weak physical and chemical characteristics such as sensitivity to dehydration and moisture contamination during initial hardening reaction, a prolonged setting reaction time, and a rough surface texture.⁵ In order to overcome these disadvantages, enhance handling characteristics, increase working times, and improve esthetic properties, materials such as high-viscosity GIC (HVGIC), resin-modified GIC (RMGIC), and reinforced GIC (RFGIC) were developed by changing the formulations of several GIC-based restorative materials.^{1,6}

In order to achieve the ideal esthetic, the restorative materials should be able to mimic the tooth in terms of color, translucency, and surface texture and they should exhibit long term color stability.⁷ The discoloration of restorative materials are explained with absorption and adsorption mechanisms of staining agents due to intrinsic and extrinsic factors.⁸ The intrinsic discolorations are described as the discoloration of restorative material arising from the oxidation between resin matrix and filler components.⁹ The exogenous discoloration however, depends on the type of staining particles, the surface roughness,

the type of restorative material, and staining solution exposure time.¹⁰ Exogenous discoloration occurs generally as a result of the consumption of colored beverages.⁸

In order to prevent the possible negative results in physical features due to liquid contamination, manufacturer's recommend the use of GICs together with surface coating resin. It was reported that the applying coating resin to the GICs gives the material gloss, prevents the decrease in the translucence of material in the course of time, provides a smooth surface by filling the gaps arising from material and finishing process, decreases the moisture sensitivity in the short term, increases the fracture and wear resistance of restoration and improves the structural properties of the material.¹¹ The effects of coating resin on the mechanical properties of GICs have been previously reported¹²⁻¹⁴ but the studies on the effect of coating resin application on the coloration mainly remained limited to the composite resins.¹⁵⁻¹⁷

This study aimed to evaluation of the color stability of coated and uncoated 4 different GIC-based restorative materials after immersed in various staining solutions. The null hypotheses were (1) GIC type has no effect on color stability; (2) different staining solutions and immersion period would not show significant difference on the color stability; (3) coating of GICs would not change the staining susceptibility.

MATERIALS AND METHODS

This study was designed as an in vitro research. The types and contents of dental restorative materials used in the present study are presented in *Table 1* and the details of solutions in *Table 2*.

Table 1: Description of the materials.

Material (Code)	Manufacturer	Type	Composition	Batch Number
<i>Riva Light Cure (RLC)</i>	SDI, Victoria, Australia	RMGIC	Fluoro-aluminosilicate glass/ Polyacrylic acid Aluminium- fluoro-silicate Calcium-aluminium-zinc-	K1111265EG
<i>Chemfil Rock (CR)</i>	Dentsply, DeTrey, Konstanz, Germany	Zinc RFGIC	fluorophosphor silicate glass, iron oxide pigments, titanium dioxide pigments/Polycarboxylic Acid, water, tartaric Acid	1903000819

Riva Self Cure HV (RSC)	SDI, Victoria, Australia	GIC	Fluoro-aluminosilicate glass/ Polyacrylic acid/Tartaric acid	C1114854F
Zirconomer (Z)	SHOFU Inc, Kyoto, Japan	Zirconia RFGIC	Alumino-fluoro-silicate glass, zirconium oxide/Polyacrylic acid, deionized water, tartaric acid	07183080
Riva Coat	SDI, Victoria, Australia	Light-cured resin coating	Acrylic monomer	190107

Table 2: Immersion solutions used in the study.

Product	Material type	Manufacturer	pH
Cola	Soft drink	The Coca-Cola Co., Istanbul, Turkey	2.5
Orange juice	Fruit juice	Dimes, Istanbul, Turkey	3.9
Chocolate milk	Milk	Danone, Istanbul, Turkey	6.6
Distilled water	Water	Polifarma, Tekirdağ, Turkey	6.4

Specimen Preparation

Specimens were made following the manufacturers' directions, placed into teflon moulds (2mm-thickness and 5mm-diameter) and held between glass slabs with polyester-mylar strip onto both sides under finger pressure to form a smooth surface. The specimens in the Chemfil Rock, Riva Self Cure and Zirconomer group were kept in the mold during the initial cement setting. Only the specimens in the Riva Light Cure group were polymerized from each surface according to the manufacturer's directions with a LED polymerization light (Elipar Freelight 2, 3M ESPE, Germany, 1.200mW/cm²). Polymerization device was tested by a radiometer (Hilux UltraPlus, Benlioglu Dental, Ankara, Turkey). All specimens were taken out from the mold and a total of 256 specimens (64 from each GIC group) were prepared. A caliper was used to measure the final thickness of the specimens (UltraCal V, Fowler, Sylvac, Swiss) (2±0.1 mm). Each different GIC specimens were divided randomly into two subgroups as 32-coated and 32-uncoated specimens. Thirty-two of the specimens prepared using the same GIC were coated with Riva Coat according to manufacturers' directions using the same LED light curing device. Before color measurement the specimens were immersed in distilled water for 24 hours at 37°C.¹⁸

Discoloration measurements and immersion cycles

The spectrophotometer (VitaEasysshade V, Vita Zahnfabrik, Bad Sackingen, Germany) used in the present study and calibrated before every color measurement. The color measurements of specimens were performed on standard neutral gray background (Munsell N7 neutral gray color) by the same operator (BÇ) with D65 illuminant light. After drying the specimens using a tissue paper, the measurements were repeated 3 times on the same surface of each specimen and the mean L*, a*, and b* values were measured. The initial color measurement values (L₀, a₀, b₀) were obtained from specimens immersed in distilled water at 37°C for 24 hours. The coated and uncoated specimens were randomly divided into 4 groups (n=8) and immersed in 4 different solutions (cola, orange juice, chocolate milk, water) then incubated in an airproof and dark environment at 37°C. The immersion solutions were refreshed every day during the 7-day test period. The color measurements were repeated on the 1st and 7th days as explained before.

The color change values were obtained at the end of the 1st and 7th days by using CIEDE2000 formula and recorded for assessment periods t1 (0th-1st day) and t2 (1st- 7th day), respectively. The formula used is below:

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

$\Delta L'$, $\Delta C'$ and $\Delta H'$ in the CIEDE formula represent the differences in parameters lightness, chroma, and hue, respectively. S_L , S_C , and S_H are the weighting functions for the L^* , a^* and b^* coordinates, respectively. The parametric factors (K_L , K_C and K_H) for changes in experimental conditions were set to 1:1:1. And finally, the interaction between chroma and hue differences in the blue region is accounted for by R_T (a rotation function).¹⁹ According to CIEDE2000, the threshold values for perceptibility and acceptability were set as 0.8 and 1.8, respectively.²⁰

Statistical Analysis

Data were analysed using the statistical package of the SPSS for Windows, Version 19.0 (IBM, Chicago, IL, USA). Comparison between GICs color stabilities by the solutions was performed using Kruskal-Wallis test and paired comparisons were performed using Dunn-Bonferroni test. The

comparisons between assessment periods for each group were performed using Wilcoxon test. p-values <0.05 was considered significant.

RESULTS

ΔE_{00} values of the GICs after immersed in various beverages are presented in *Table 3*. Cola was the solution that stained RLC and RLC+ at the highest level in t1 and t2. Moreover, the chocolate milk stained RLC+ in t2 at the highest level. Cola and chocolate milk stained CR in t1 at the highest level, whereas cola colored it at the highest level in t2. Different solutions had no significant effect on the color change of CR+ in t1 and t2. Cola was the solution stained RSC in t1 and t2 at the highest level. Chocolate milk stained RSC+ at the highest level in t2, whereas cola was the solution stained in t1 at the highest level. Chocolate milk stained Z at the highest level in t1 and orange juice was the solution stained in t2 at the highest level. Different solutions had no significant effect on the color change of Z+ in t1 and t2 (*Table 3*).

Table 3: Minimum-maximum (median) of color change values (ΔE_{00}) of glass ionomer-based restorative materials (GICs) after immersion in different solutions in same time interval.

Materials	Immersion period	Staining Solutions				p value
		Cola	Orange juice	Chocolate milk	Water	
<i>Riva Light Cure</i>	t1	5.7-15.9 (11.3) ^A	1-6.8 (3.3) ^B	1.4-5 (2.4) ^B	1.2-3 (2.7) ^B	<0.001
	t2	3.2-11.5 (10.3) ^A	0.6-4.9 (2.3) ^B	0.7-2.8 (1.5) ^B	0.6-2 (1) ^B	<0.001
<i>Riva Light Cure+</i>	t1	1.8-8.6 (5.1) ^A	0.3-5.2 (2.4) ^{AB}	0.9-5.1 (1.8) ^B	1.5-2.5 (2.2) ^{AB}	0.023
	t2	5.1-13.5 (8.1) ^A	1.3-2.7 (2) ^B	7.5-11.6 (10.4) ^A	1.2-2.2 (1.3) ^B	<0.001
<i>Chemfil Rock</i>	t1	1.2-6.5 (2) ^A	0.9-3.9 (1.5) ^{AB}	1-5.6 (1.4) ^A	0.2-1.2 (0.7) ^B	0.002
	t2	1.2-7 (2.5) ^A	1.2-3.7 (2.1) ^{AB}	0.3-3.1 (0.8) ^B	1.1-2.3 (1.8) ^{AB}	0.021
<i>Chemfil Rock+</i>	t1	0.3-4.1 (2.6)	0.4-6.8 (2)	0.4-5 (2.3)	0.2-1.3 (0.8)	0.73
	t2	0.6-8.3 (2.9)	0.5-6.3 (1.7)	0.5-4.9 (0.8)	1.2-1.5 (1.3)	0.102
<i>Riva Self Cure</i>	t1	1.6-4.7 (2.3) ^A	0.7-4.5 (0.9) ^B	0.4-4.3 (2.5) ^{AB}	1-2 (1.2) ^{AB}	0.042
	t2	4.5-46.4 (22.7) ^A	0.9-4.1 (1.6) ^{AB}	0.1-1.8 (0.6) ^B	0.5-1.8 (1.3) ^B	<0.001
<i>Riva Self Cure+</i>	t1	0.6-7	0.5-7.3	0.7-3.1	0.2-1	0.002

		(2.8) ^A	(1.2) ^{AB}	(1.9) ^A	(0.5) ^B	
	t2	1-13.3	0.5-4	6.2-11.2	1.1-1.8	
		(4) ^{AB}	(1.2) ^B	(8.6) ^A	(1.5) ^B	<0.001
Zirconomer	t1	0.5-35.3	1.4-15.8	4.6-35.1	1.1-2.4	
		(5.6) ^{AB}	(9) ^{AB}	(12) ^A	(1.9) ^B	0.006
	t2	1.1-23.8	2.6-19.8	1-34.5	1.2-2.4	
		(2.6) ^{AB}	(12.4) ^A	(5) ^{AB}	(1.7) ^B	0.017
Zirconomer+	t1	1.4-5.8	0.7-4.2	1.7-5.1	3.3-4	
		(3.2)	(1.8)	(2.1)	(3.7)	0.194
	t2	1-7.5	0.5-7.1	0.6-3.4	1.2-2.3	
		(3.2)	(2.3)	(1.4)	(2)	0.269

+: refers to the specimens coated with Riva Coat

Different uppercase letters (A, B) indicate statistically significant differences (in a row) ($p < 0.05$)

All the ΔE_{00} values obtained from all the specimens immersed in cola were higher than the acceptability threshold ($\Delta E_{00}=1.8$). The immersion solutions did not show any significant color change in the CR+ and Z+ at any time period (Table 3).

The ΔE_{00} values of GICs used in the present study in different immersion periods are presented in Table 4. In both periods, the group showing the

highest ΔE_{00} value was Z, the coating in this group slightly reduced the discoloration but yielded no significant difference. RSC+ group showed the minimum discoloration in t1 but ΔE_{00} values significantly increased after the 1st day ($p < 0.001$). There was no statistical differences with regard to ΔE_{00} values between coated and uncoated specimens of the same GICs evaluated between themselves at same time periods.

Table 4: Minimum-maximum (median) of color change values (ΔE_{00}) of glass ionomer-based restorative materials (GICs) after different immersion periods.

Materials	Immersion Period		<i>*p</i>
	t1	t2	
<i>Riva Light Cure</i>	1-15.9 (3.1) ^a	0.6-11.5 (1.7) ^{ab}	0.001
<i>Riva Light Cure</i> +	0.3-8.6 (2.3) ^{abc}	1.2-13.5 (3.9) ^a	0.006
<i>Chemfil Rock</i>	0.2-6.5 (1.3) ^{bc}	0.3-6.9 (1.9) ^{ab}	0.568
<i>Chemfil Rock</i> +	0.2-6.8 (1.6) ^{bc}	0.5-8.3 (1.3) ^b	0.866
<i>Riva Self Cure</i>	0.4-4.7 (1.7) ^{bc}	0.1-46.4 (1.5) ^{ab}	0.272
<i>Riva Self Cure</i> +	0.2-7.3 (1.2) ^c	0.5-13.3 (3.1) ^{ab}	<0.001
<i>Zirconomer</i>	0.5-35.3 (5.3) ^a	1-34.5 (2.8) ^a	0.080
<i>Zirconomer</i> +	0.7-5.8 (3.4) ^{ab}	0.5-7.5 (2) ^{ab}	0.084
**p	<0.001	<0.001	

+: refers to the specimens coated with Riva Coat

*Wilcoxon Signed Rank Test, **Kruskall Wallis Test ($p < 0.05$)

Different lowercase letters (a, b, c) indicate statistically significant differences (in a column)

DISCUSSION

This study, color stability of four different GIC-based restorative materials, on which a surface coating was applied or not, after exposure to different immersion solutions was investigated. According to the results obtained, it was found that type of restorative material, type of staining solution, and immersion time had effect on the color stability of GICs; thus, the first two

hypotheses have been rejected and the third partially accepted.

In addition to all the positive features of GICs, they are often preferred as a restorative material in paediatric dentistry due to their ease of clinical application.^{3,4} Therefore, the importance of color stability in GIC is parallel to the increase in esthetic expectation. In paediatric dentistry, long-term color stability should not only be considered for aesthetic reasons and loss of

money from repeated restorative procedures but also for the fact that more frequent visits to dentist might cause dental anxiety and behavior management problems among children.²

In recent years, the consumption of soft drinks significantly increased among children and youth. Especially flavors such as chocolate, banana, and strawberry added to milk encourage consumption.²¹ Although there are studies in the literature about the coloration of dental materials in different solutions^{3,6,8,10,21,22}, studies evaluating the effects of surface coating application on the color stability of GICs is still limited.^{23,24} The present study was designed since there was no study evaluating the effect of surface coating application on the color stability of GICs, which are the materials widely used in dental treatments of children, after exposure to beverages commonly consumed by children.

The immersion time used in the present study was designed by taking reference from the study of Guler *et al.*²² In their study, authors assumed the average consumption duration of a beverage to be 15 minutes and average daily consumption to be 3.2 cups. Thus, 1-day immersion simulates the amount of beverage consumed in approximately 1 month. In this study, color change values at t1 (0th-1st day) and t2 (1st-7th day) were compared. Thus, it was aimed to evaluate the short and long term effect of coating on the color change of GICs.

In the present study Riva Coat was chosen as a coating material. Because two GIC materials (RLC and RSC) were produced by the Riva Coat's manufacturer and there was no study evaluating the efficiency of Riva Coat surface coating resin material on GICs in the literature.

In this study, the color changes were measured using a spectrophotometer. When the literature was examined, CIE Lab was generally used to detect discoloration of restorative materials stored in various beverages. However, the International Commission on Illumination has developed the CIEDE2000 formula, which is more accurate in terms of perceptibility and acceptability due to the inadequacy of the CIE

Lab formula.²⁵ The CIEDE2000 formula was also used in this study, as it proved to be more up-to-date and appropriate for detecting color changes.²⁶

Differences in composition and setting of GICs may affect their staining susceptibility.²⁷ The water content of GICs is an also important determinant for color stability.⁸ Compared to RMGICs, GICs contain more water, therefore their water absorption capacity is reduced, resulting in less staining.²³ When t1 and t2 time periods were compared, there was no significant differences in ΔE_{00} values of the uncoated RSC, while a statistically significant increase was observed in the ΔE_{00} value when the RSC was coated. In RLC, ΔE_{00} values showed a significant decrease after the 1st day when uncoated but a significant increase was obtained when coated. There are many studies supporting that surface coating resin should be applied on the surface of GICs and RMGICs.^{24,28} But the manufacturer of RLC does not recommend the use of surface coating but it is recommended to not eat anything for a minimum of 1 hour after the material hardens. In this study, one of the materials showing the highest color change was RLC. This result is in parallel with the previous studies reporting that GIC has higher color stability than RMGICs.²⁹ Zimmerli *et al.*³⁰ was reported that the surface coatings have the potential of decreasing the surface porosity and they might reduce the color change by protecting the material from external factors but they tend to break up from the surface. This in vitro study was completed within 7 days, simulating approximately 7-month of staining, so no separation from the surface was occurred in the coating material. Using a surface coating is not recommended by the manufacturer of CR but in a previous study, it was stated that coating the CR enhanced the mechanical properties.³¹ The manufacturer of Z recommends cocoa butter as a coating material. However, this material can cover the restoration surface for a short time and it may fall short in moisture control. In our study, coating material was also applied on the surfaces of CR and Z specimens, included in the RFGICs, and no significant differences were found between the ΔE_{00} values of the coated and uncoated specimens at the same

time interval or within the coated and uncoated specimens at different time intervals. The coated CR and Z did not show any significant differences in discoloration when immersed in different immersion solutions in t1 and t2. It has been observed that the effects of the solutions on color change are protected with when CR and Z were coated. The consumption of acidic drinks is very common among all the adolescent and children. Acidity of these beverages might damage the properties of restorative materials.³² In a study evaluating the effect of acidic drinks on bacterial adhesion in GICs, it was reported that cola caused the deterioration of GICs surface layer and consequently, an increase in bacterial adhesion. Even if the use of surface coating material decreased the bacterial adhesion, it caused an increase in bacterial adhesion due to the rapid dissolution of coating material under the acid effect.³³ In this study, only the color changes of GICs were compared, bacterial adhesion was not evaluated. Among the solutions used in the present study, cola was found that caused in the highest level of color change in coated and uncoated specimens. This might be because it has a lower pH than other solutions. In addition, cola is a brown carbonated beverage which gains its color by adding caramel that displays colors ranging from pale yellow to deep brown.³⁴ Thus, clinicians should warn the patients, who consume cola at high amounts, about the discoloration of GIC-based dental restorations. In this study, ΔE_{00} values of specimens in cola in all times were found to be higher than the acceptability threshold. Following cola, chocolate milk was the solution yielding the second-highest color change. Although pH value of chocolate milk is more alkaline than the other solutions, it is thought that the staining particles in solution might cause discoloration. These results are in parallel with the previous studies stated that the color changes of restorative materials may vary depending on the size of particles in the staining solution and the restorative material's components.³⁵

As expected, the lowest color change at t1 and t2 was observed in distilled water in all GIC groups. Consequently, it was found that the color change was not related to whether the GICs were

coated, but with color change being associated with GIC type and immersion time. Since this study is in-vitro, it cannot fully provide clinical applications. Saliva generally acts as a buffer for pH of beverage and it dilutes the concentration of beverages in the mouth. However, in this study, the specimens were stored in undiluted beverages for 7 days. Moreover, only limited time effects of the coating were investigated. Given the fact that longer protection is needed in the oral environment, long-term studies are needed. Besides, the absence of previous studies testing similar GICs and methodology together made it difficult for comparison.

CONCLUSIONS

Within the limitations of present study, all GIC groups exhibited less color stability than other solutions when immersed in cola. RFGICs showed more stability in terms of color change in the long term than other GICs. Determining the role of coatings in the color stability and which GIC material is sensitive to the color changes are very important for in estimating the lifetime of the restoration.

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None to declare.

CONFLICT OF INTEREST

Author confirm that he has no conflict of interest.

ÖZ

Amaç: Çalışmanın amacı, cam iyonomer içerikli (CIS) farklı restoratif materyallerde yüzey örtücü uygulamasının, çocukların sıklıkla tükettiği içeceklerin renk stabilitesi üzerine etkisini değerlendirmektir.

Gereç ve Yöntemler: Bu çalışmada dört farklı CIS ve bir yüzey örtücü kaplama materyali kullanıldı. Her bir CIS 'den disk şeklinde on altı örnek yapıldı ve kaplanmamış ve kaplanmış olmak üzere iki gruba ayrıldı (n=8). Renklenmeleri için örnekler yedi gün boyunca kola, portakal suyu, çikolatalı süt ve su solüsyonlarında bekletildi. Renk ölçümleri, solüsyonlarda bekletilmeden önce başlangıçta ve 1. ve 7. günlerin sonunda spektrofotometre kullanılarak yapıldı. Renk değişimleri (ΔE_{00}), CIEDE2000 formülü kullanılarak hesaplandı. Veriler Kruskal-Wallis ve Wilcoxon testi ile analiz edildi ($p<0.05$). **Bulgular:** Kaplanan ve kaplanmayan tüm CIS'lerde ΔE_{00}

değerleri, yedi günlük bekletilme sonrasında tüm solüsyonlarda artış gösterdi. Kolada bekletilen tüm örneklerden elde edilen ΔE_{00} değerleri, kabul edilebilirlik eşiğinin üzerinde olduğu tespit edildi. Aynı CIS'lerde, aynı zaman dilimlerinde kaplanmış ve kaplanmamış örnekleri arasında ΔE_{00} değerleri açısından istatistiksel bir fark bulunamadı. **Sonuçlar:** CIS'lerin kaplanması, nispeten iyi bir renk stabilitesi sergiledi ve renklenmeye karşı koruma sağladı. Çocuk diş hekimliğinde CIS içerikli dental materyaller tercih edilirken renklenme etkileri de göz önünde bulundurulmalıdır. **Anahtar kelimeler:** Yüzey örtücü ajan, cam-iyonomer siman, renklenme.

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