

Water Sorption and Solubility of a High-viscous Glass-Ionomer Cement after the Application of Different Surface-Coating Agents

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Abstract

Aim: The aim of this study was to compare the effect of different surface coating agents on water sorption and solubility of a high-viscous glass ionomer cement (GIC). **Materials and Methods:** A high-viscous GIC (EQUIA Forte, GC, Tokyo, Japan) was used for this study. Sixty disc-shaped specimens (8 mm × 2 mm) were prepared from material. Specimens were divided six subgroups and five different coating systems were applied on specimen surfaces. Other groups were used as the control group ($n = 10$) (Group 1: Control, Group 2: Scotchbond Universal Adhesive (3M ESPE, St. Paul, MN, USA), Group 3: Petroleum jelly (Vaseline, India, Lever Ltd.), Group 4: BisCover LV (Bisco, Schaumburg, IL, USA), Group 5: EQUIA Forte Coat (GC, Tokyo, Japan), Group 6: Final Varnish LC (VOCO, Cuxhaven, Germany). All specimens were prepared according to the manufacturer's instructions and subjected to water sorption and solubility tests based on the ISO 4049 requirements. Data were analyzed by paired samples *t*-test, one way analysis of variance, *post hoc* Tukey HSD, and Tamhane's T2 tests ($\alpha = 0.05$). **Results:** Equia Forte Coat and Final Varnish LC were more successful in terms of water sorption, but Final Varnish LC was more successful in terms of solubility. **Conclusion:** Within the limitation of this study, it can be concluded that light-cured surface coatings, especially Final Varnish LC were more successful than other groups in terms of water sorption and solubility.

Keywords: Glass ionomer cement, solubility, surface coating, water sorption

INTRODUCTION

Conventional glass ionomer cements (GICs), which were introduced to dentistry in 1972 by Wilson and Kent, were introduced under the name of aluminosilicate polyacrylic acid due to the fact that it is a hybrid material formed by silicates and polycarboxylate cements.^[1,2]

GIC, which carry the optical and fluoride release properties of silicates with chemical adhesion to enamel and dentin and biocompatibility properties of polyacrylic acid matrix, are also widely used because of their ability to exhibit thermal expansion coefficient similar to dentin. However, glass ionomers have disadvantages such as low wear resistance, long-hardening times, poor esthetic properties, and early moisture sensitivity. These disadvantages also reduce the clinical success of GIC restorations.^[1,3,4]

Water sorption and solubility are the properties that cannot be completely controlled and that affect the physical,

mechanical, and chemical properties of all restorative materials. This situation is one of the factors that should be emphasized, especially for GIC in which setting reaction time is long. Water loss during the setting period may lead to micro cracks in the structure of the restoration, volumetric changes, and adhesion weakness. Whereas, surface erosion can be seen with the loss of calcium and aluminum ions from the surface of the restoration in case of early contact with moisture and decreases the translucency of restoration.^[5,6]

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Many studies have been carried out to reduce susceptibility to moisture in the early period of GIC and hence increase physical and mechanical properties. Clinicians primarily tried to use resin-containing agents, varnishes, petroleum gels to cut the contact of the GIC surface with water. Recent studies have shown that coating of surfaces of GIC have a positive effect on the physical and mechanical properties.^[3,6-8]

The aim of this study is to compare the effect on water sorption and solubility of different surface-coating agents applied on a high-viscosity GIC.

The null hypothesis of the study is that different surface-coating agents applied on high viscosity GIC do not affect the water sorption and solubility of GIC.

MATERIALS AND METHODS

In this study, the effect of different surface-coating agents on the water sorption and solubility of GIC was compared. Information about the materials used in the study and their contents is given in Table 1.

A total of 60 samples were prepared using disc-shaped mold (8 mm diameter, 2 mm thickness) from glass ionomer material (EQUA Forte, GC, Tokyo, Japan). The restorative material was prepared according to the manufacturer's instructions. Strip bands were placed at both sides of each disk and then sandwiched between two glass plates with a weight of 400 g. A 5-min time was allowed for the specimens to set. Next, the samples were removed from the molds, were cleaned, 600 grit carbide papers were used for surface standardization. Moreover then, their volumes were calculated using digital caliper (Absolute Digimatic, Mitutoyo Corp., Kawasaki, Japan). The volume (V) of each specimen was calculated as follows in cubic millimeters using the mean thickness and diameter:

$$V = \pi r^{2h} = \text{mm}^3$$

Where, r is the mean sample radius (diameter/2) and h is the mean sample thickness.

Specimens were divided six subgroups and five different coating systems were applied on specimen surfaces. Other group was used as the control group ($n = 10$) (Group 1: Control, Group 2:

Scotchbond Universal Adhesive (3MESPE, St. Paul, MN, USA), Group 3: Petroleum jelly (Vaseline, Lever Ltd.), Group 4: BisCover LV (Bisco, Schaumburg, IL, USA), Group 5: EQUA Forte Coat (GC, Tokyo, Japan), and Group 6: Final Varnish LC (VOCO, Cuxhaven, Germany). The surface-coating agents were applied to the samples as a single layer with the help of applicator according to the manufacturer's instructions. Then, the samples were kept in a desiccator for 24 h until a constant weight was obtained. After 24 h, the samples were weighed with a digital scale (Japanese Shimadzu SAUW-220D) with a sensitivity level of 0.0001 g and recorded as M1 (μg). After these operations, and samples were left in distilled water and incubated in the oven (Nüve EN-120, Ankara, Turkey) for 24 h and 7 days. At the end of these periods, the samples removed from the solution were dried with blotting paper, the weight measurements were repeated and recorded as M2a and M2b. Then, the samples were placed in the desiccator again, and the weight measurements were repeated after 24 h (M3). Water sorption and solubility were calculated using the following formulas in accordance with ISO 4049 standards:

$$\text{WSO } (\mu\text{g}/\text{mm}^3) = \frac{M2a,b - M3}{V}$$

$$\text{WSL } (\mu\text{g}/\text{mm}^3) = \frac{M1 - M3}{V}$$

Where M1 is the specimen mass after desiccation (mg), M2a is the specimen mass 1 day after immersion, M2b is the specimen mass 7 days after immersion (mg), M3 is the specimen mass after second desiccation (mg), and V is the specimen volume before immersion (mm^3). For each group, the means and standard deviations for solubility, sorption ($\mu\text{g}/\text{mm}^3$) were calculated.

Statistical analysis

Statistical analysis was performed using the SPSS software version 20 (IBM, Chicago, IL, USA). Kolmogorov–Smirnov test was used to determine the distribution of the data. In addition, normality verification (equality of variances) of the data was performed using Levene's test. Paired samples *t*-test was used to compare the groups in terms of storage times for each material. One-way analysis of variance (ANOVA) and

Table 1: Details of investigated materials

Products	Manufacturer	Composition
EQUA Forte	GC, Tokyo, Japan	Powder: fluoroaluminosilicate glass, polyacrylic acid, iron oxide Liquid: polybasic carboxylic acid, water
Scotchbond Universal Adhesive	3M ESPE, St. Paul, MN, USA	MDP, dimethacrylate resins, HEMA, Vitrebond™ copolymer, filler, ethanol, water, initiators, silane
Petroleum jelly	Vaseline, India Lever Ltd.	Mineral oils, paraffin and microcrystalline waxes
BisCover LV	Bisco, Schaumburg, IL, USA	Ethanol 50%-75%, dipentaerythritol pentaacrylate 30%-50%, camphorquinone 1%-5%
EQUA Forte Coat	GC, Tokyo, Japan	MMA 25%-50%, photoinitiator 1%-5%, synergist 15-5%, phosphoric acid ester monomer 15-5%, BHT <1%
Final Varnish LC	VOCO, Cuxhaven, Germany	Bis-GMA, diurethanedimethacrylate, HEDMA, catalyst
MMA: Methyl methacrylate, BHT: Butylated hydroxytoluene, Bis-GMA: bisphenol A glycerolate dimethacrylate, HEDMA: 2-hydroxyethyl dimethacrylate, HEMA: 2-hydroxyethyl methacrylate, MDP: 10-Methacryloyloxydecyl dihydrogen phosphate		

Tukey *post hoc* tests were used to compare the groups in terms of water sorption. In addition, one-way ANOVA was also used to compare the groups in terms of solubility. However, Tamhane's T2 *post hoc* test was used for the comparison of groups since the variances were not homogeneous in solubility groups. The value of $P < 0.05$ was considered as statistically significant.

RESULTS

Table 2 shows the mean and standard deviations for the water sorption of different surface coating agents applied on GIC. As a result of one-way variance analysis performed separately for groups of 1 day and 7 days in terms of water sorption, statistically significant differences were obtained between the groups ($P < 0.001$). In both periods, the most water absorbing group was found to be the control group and the least water absorbing group was EQUIA Forte Coat and Final Varnish LC ($P < 0.05$) [Table 2]. According to Paired samples *t*-test results, a statistically significant difference was found between the storage times for each material. The amounts of water sorption in 7 days were significantly higher than 1 day in all groups ($P < 0.05$) [Table 2].

Table 3 shows the mean and standard deviations for the solubility of different surface-coating agents applied on GIC. As a result of one-way variance analysis performed for all groups in terms of solubility, statistically significant differences were obtained between the groups ($P < 0.001$). As a result of the Tamhane's T2 *post hoc* test, it was found that the solubility values of light-curing surface-coating agents and especially the Final Varnish LC group were found to be lower than the other groups ($P < 0.05$) [Table 3].

DISCUSSION

Setting reaction of GIC is occurred by the acid–base reaction and chelation formation between the alumina silicate glass powder and the polyacid liquid in the structure of GIC.^[9,10] Calciumpolyacrylate cross-links resulting from chelation are responsible for the early setting mechanism of GIC in the first 3–5 min. The late-stage setting mechanism is the process of formation of aluminopolyacrylate cross-links formed by Al^{+3} ions released within 24–48 h. Aluminum polyacrylate cross-links are more resistant to water.^[11]

GIC is sensitive to hydration and dehydration during both the early and late setting period. GIC needs to be protected from moisture until the reaction is complete in these periods when the physical and mechanical properties are weak.^[12] Studies have shown that surface-coating processes improve the mechanical properties of materials.^[13-15] In this study, five different surface-protective materials applied on GIC were compared in terms of water sorption and the solubility values. As a result, statistically significant differences were found between the groups in terms of both water sorption and solubility values ($P < 0.05$). In addition, the amounts of water sorption in 7 days were significantly higher than 1 day in all groups ($P < 0.05$). Therefore, the hypothesis was rejected. EQUIA Forte Coat and Final Varnish LC groups showed less water sorption compared to the other groups while the Final Varnish LC group was found to be less soluble. Light-cured surface coatings were generally more successful than petroleum jelly group. Serra *et al.*^[8] found that water dehydration and contamination during the initial setting phase weakened the physical properties of the glass ionomer restoration and that the surface coatings were effective in maintaining the setting reaction of GIC in their first setting phase. Similar to the present study, although petroleum jelly was found to be less successful than other materials, it was shown to be useful in preventing water absorption during early moisture contamination compared to the control group. Fatima *et al.*^[16] also stated that the hardness value of the GIC coated with petroleum jelly is similar to the control group and the reason for this is the easy washing of during the setting reaction. Brito *et al.*^[3] also found similar results.

Except for petroleum jelly, all surface coating materials used in this study are light cured and the polymerization process is thought to have an effect on the setting reaction of GIC. The light curing unit (Elipar Freelight II, 3M ESPE, St. Paul MN, USA) used in the present study has a power output of 1200 mW cm², which causes some heat increase.^[17,18] It has been reported that such a temperature increase will cause an acceleration in the setting reaction at the surface portions of the samples. As a result, both the acceleration of the setting reaction and the coating of the material surface will result in shorter exposure to moisture contact. Therefore, it is said that light-cured

Table 2: Mean±standard deviation for water absorption ($\mu\text{g}/\text{mm}^3$) of glass ionomer cement after the application of different surface-coating agents and statistically comparison results ($n=10$)

Groups	Water sorption (1 day)	Water sorption (7 days)	P
Control	99.49±9.04 ^{d,A}	115.01±8.35 ^{b,B}	0.0001*
Scotchbond universal adhesive	81.21±12.62 ^{b,c,A}	106.50±8.21 ^{b,B}	0.0001*
Petroleum jelly	70.91±17.37 ^{b,A}	85.85±11.95 ^{a,B}	0.008*
BisCover LV	93.56±11.41 ^{c,d,A}	105.97±12.76 ^{b,B}	0.001*
EQUIA forte coat	53.18±12.67 ^{a,A}	76.70±16.82 ^{a,B}	0.0001*
Final varnish LC	64.24±12.55 ^{a,b,A}	82.14±15.75 ^{a,B}	0.0001*
P	0.001*	0.001*	

* $P < 0.05$. Different lowercase letters within the same column and different uppercase letters within the same row indicate an significant difference

Table 3: Mean \pm standard deviation for solubility ($\mu\text{g}/\text{mm}^3$) of glass ionomer cement after the application of different surface coating agents and statistically comparison results ($n=10$)

Groups	Solubility
Control	-10.91 ± 11.78^a
Scotchbond universal adhesive	-2.14 ± 4.99^a
Petroleum jelly	55.29 ± 15.11^b
BisCover LV	$4.32 \pm 8.85^{a,c}$
EQUIA Forte Coat	5.06 ± 3.61^c
Final Varnish LC	-4.67 ± 3.23^b
P	0.001*

* $P < 0.05$. Different lowercase letters within the same column indicate a significant difference

coating materials are more advantageous.^[11] Similarly, in the present study, it was found that light-cured coating materials absorbed less water than control group and petroleum jelly group. Biscover, one of the surface coating materials used in our study, absorbed more water than other light-cured materials. Biscover was polymerized using halogen light device (Hilux Ultra Plus, Benlioglu Dental, Ankara, Turkey) according to manufacturer's instructions. Since the power of this light device ($800 \text{ mW}/\text{cm}^2$) is lower than that of the light-emitting diode, the less efficient polymerization of the quartz-tungstenhalogen may have contributed to this.^[19]

Light-curing coating agents have been used to isolate cement from saliva during the setting reaction of GIC, as well as to block any cracks or porous structures formed on the surface.^[20] Although Scotchbond Universal Adhesive is cured by light, the excess water sorption of cement may be due to the acid structure in the bonding affecting the cement surface. Leite *et al.*^[21] compared vickers hardness of GIC based on early moisture contact and drying. As a result, they found that preventing the cement for 24 h from moisture contact allows a significant increase in hardness compared to values immediately after initial hardening. Earl *et al.*^[22] have studied the movement of water using Tritium-labeled water in GIC, the surface of which is coated with water, and found that water movement in GIC prepared using surface coating is reduced. In literature, researchers state that surface coatings to be able to reduce early moisture contact and advanced water sorption should be applied to make glass ionomer restorations more successful.^[7,8]

The limited part of this study is that thermal changes and wear rates cannot be imitated directly because of not working in the mouth.

CONCLUSION

Within the limitation of this study, it can be concluded that light-cured surface coatings especially Final Varnish LC was more successful than other groups in terms of water sorption and solubility.

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Conflicts of interest

There are no conflicts of interest.

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