Effectiveness of surface protection for glass-ionomer, resin-modified glass-ionomer and polyacid-modified composite resins

Serpil KARAOĞLANOĞLU1, Nilgün AKGÜL1, Hatice Nur ÖZDABAK1 and Hayati Murat AKGÜL2

1Department of Restorative Dentistry, School of Dentistry, Atatürk University, Erzurum 25240, Turkey
2Department of Oral Diagnosis and Oral Radiology, School of Dentistry, Atatürk University, Erzurum 25240, Turkey
Corresponding author, Nilgün AKGÜL; E-mail: nalgul2000@yahoo.com

The purpose of this study was to evaluate the effectiveness of several surface protectors for a glass-ionomer, a resin-modified glass-ionomer, and a polyacid-modified resin cement by determining dye uptake spectrophotometrically.

378 samples, made up of Ionomil U, Vitremer, and Dyract, were prepared and divided into groups of seven each. Positive and negative control specimens remained unprotected while the experimental specimens were protected with Finishing Gloss, Protect-It, LC Varnish, Adper Single Bond, or a nail varnish. The experimental groups and positive controls were immersed in 0.05% methylene blue solution, while the negative controls were immersed in deionized water. Results were evaluated using variance analysis.

Of the Ionomil U group, Adper Single Bond exhibited the least effective surface coating among the materials tested, while the best surface protection was obtained with LC Varnish in the Dyract group. However, no statistically significant differences were observed in the Vitremer group.

Key words: Surface protection, Glass-ionomer cement, Polyacid-modified composite resin

INTRODUCTION

Conventional glass-ionomer cement, which is a popular restorative material commonly used in dentistry for a long time, is formed by an acid-base reaction between aluminosilicate glass and a 40—50% aqueous solution of acrylic acid/itaconic acid copolymer stabilized with a 5% tartaric acid1-4. Ionomer cements are sensitive to hydration and dehydration during their initial setting and are frequently protected by coating materials. Initial setting occurs in a few minutes, but precipitation, gelation, and hydration take at least 24 hours, and further etching continues slowly for a much longer period5.

In recent years, developments in the field of glass-ionomer cements have led to the introduction of hybrid versions6. These materials were enhanced to overcome the problems of low initial mechanical strength and moisture sensitivity associated with conventional cements, while preserving their clinical advantages such as self-adhesion to dental tissues and fluoride release. These new materials were classified as resin-modified glass-ionomers6,7,8.

Resin-modified glass-ionomer cements have two setting mechanisms: the acid-base setting reaction and polymerization reaction9. According to McLean et al.7, resin-modified glass-ionomers are materials that set concurrently via a dominant acid-base reaction and auxiliary photopolymerization. This latter reaction can occur due to the self-cure mode of the resin phase and/or it can occur by light activation. Compared with conventional analogs, resin-modified glass-ionomer cements have been characterized as having a longer working time, a rapid set, improved appearance and translucency, and higher early strength9,10. In particular, a remarkable feature of these materials is that they can be finished and polished on the same visit11.

To overcome the technique-sensitive mixing and handling properties of resin-modified glass-ionomer cements, new materials containing acid-decomposable glass and acidic polymerizable monomers substituting the polyalkenoic acid polymer were developed12,13. These materials were termed as polyacid-modified composite resins, commonly known as compomers. A polyacid-modified resin (PMR) is a cross between a glass-ionomer and composite in that it contains a reactive fluoride glass and an acid as well as a monomer. One major and important difference between glass-ionomers and compomers lies herein: in the glass-ionomer the acid is present as a polymer, while in the compomer the acid is present as a monomer and the polymer is formed by polymerization of the monomers during curing. Another significant difference is that PMR contains no water, and reaction between the glass and acidic monomer takes place only as PMR takes up water from the environment13.

To reduce the susceptibility of conventional glass-ionomer cement and its hybrid versions to hydration and dehydration problems, surface
protected were suggested for these materials. In light of this suggestion, materials referred to as covering agents or surface sealants have been developed specifically for rebonding of restorations. Today, several commercial products are available. They are resin materials with low viscosity and a high flow rate, and that they present similar compositions. Moreover, their application technique is relatively simple.

The application of surface protection seems to preserve the water balance in the system. Another advantage of using such surface protectors is that they fill small surface voids and defects and may help to preserve the original color of the restorations by reducing the uptake of stains.

The purpose of this study was to evaluate the amount of dye absorbed by a conventional GIC, a resin-modified GIC, and a polyacid-modified composite resin and to make an analysis of the effectiveness of various surface agents for these materials by determining dye uptake spectrophotometrically.

MATERIALS AND METHODS

Materials used
A conventional glass-ionomer cement (Ionofil U, Voco, Cuxhaven, Germany), a resin-modified glass-ionomer cement (Vitremer, 3M Dental Products, St Paul, MN, USA), and a polyacid-modified resin composite (Dyrcat AP, DeTrey Dentsply, Konstanz, Germany) were selected for this study (Table 1).

Table 1  Materials used in the present study

<table>
<thead>
<tr>
<th>Product</th>
<th>Manufacturer</th>
<th>Composition*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionofil U</td>
<td>Voco, Cuxhaven, Germany</td>
<td>FAS, PAA, water</td>
</tr>
<tr>
<td>Vitremer</td>
<td>3M Dental Products, St Paul, MN, USA</td>
<td>FAS, PMAA, HEMA</td>
</tr>
<tr>
<td>Dyrcat AP</td>
<td>DeTrey, Dentsply, Konstanz, Germany</td>
<td>UDMA, TCB, TEGDMA, Trimethacrylate resin</td>
</tr>
<tr>
<td>Adper single bond</td>
<td>3M Dental Products, St Paul, MN, USA</td>
<td>BisGMA, HEMA, copolymer of polyacrylic acid, photoinitiator,</td>
</tr>
<tr>
<td>Protect it</td>
<td>Jeneric/Pentron, Inc, Wallingford, CT, USA</td>
<td>BisGMA, UDMA, TEGDMA, THFMA</td>
</tr>
<tr>
<td>Finishing gloss</td>
<td>3M Dental Products, St Paul, MN, USA</td>
<td>BisGMA, TEGDMA</td>
</tr>
<tr>
<td>LC varnish</td>
<td>Spofa Dental, A Kerr Company, Markova, Jicin, CZ</td>
<td>BisGMA, UDMA</td>
</tr>
<tr>
<td>Nail varnish</td>
<td>Colorama, CEIL-Com Exp Ltda, Sao Paulo, SP, Brazil</td>
<td>Camphor, nitrocellulose, sulfonamide, toluene</td>
</tr>
</tbody>
</table>

* Approximate composition as given by manufacturers.

Specimen preparation for experimental groups
These materials were prepared according to manufacturers’ instructions and placed in teflon disks 4.00 mm in diameter and 2.0 mm in height. These disks were first slightly overfilled with each restorative material under evaluation. Strip bands were placed at both sides of each disk and then sandwiched between two glass plates with a weight of 500 g. The specimens prepared for Vitremer and Dyrcat AP were light-cured for 40 seconds, while the Ionofil U specimens were left for 5 minutes for setting. After which, the plates and strip bands were removed, and one of the coating materials under evaluation was applied with a brush on both exposed surfaces of the specimens twice, except for the positive and negative control groups. Excess material was trimmed off, and the protected specimens were coated again.

A total of 126 specimens were prepared with each material and randomly divided into seven groups, each of which contained 18 restorations. The specimens to be coated with Adper Single Bond (3M Dental Products, St Paul, MN, USA) and Protect-It (Jeneric Pentron Inc., Wallingford, CT, USA) were etched with 37% phosphoric acid for 15 and 20 seconds respectively. Then, they were rinsed for 15 seconds, gently air-dried, and light-cured for 20 seconds. The specimens with LC Varnish (Spofa Dental, A Kerr Company, Markova, Jicin, CZ) and Finishing Gloss (3M Dental Products, St Paul, MN, USA) were not etched, but these coating materials were spread on the surface using a stream of air and
then irradiated for 20 seconds. The specimens coated with a nail varnish (Colorama, CEIL Com Exp Ind Ltda, São Paulo, SP, Brazil) were merely left to dry for 2 minutes.

**Dye penetration test**

Following the application of the surface coatings, the specimens were immersed in 0.05% methylene blue solution at 37°C, except for the negative control specimens which were immersed in deionized water. After 24 hours, the specimens were rinsed with deionized water and the surface coatings were removed with medium SofLex disks (3M Dental Products, St. Paul, MN, USA) for 5 seconds. The method used to quantify the effectiveness of surface protection was adapted from Douglas and Zakariasen, as described by Serra et al.\(^1\)\(^8\). The specimens were removed from the teflon disks, and each one was immersed separately in tubes containing 1 mL of 65% nitric acid for 24 hours. After which, standard and experimental nitric acid solutions were diluted with 2 mL of deionized water. The solutions were filtered and centrifuged, and finally the absorbance of methylene blue in nitric acid was determined by a spectrophotometer (Samsung Syncmaster 750s) at 600 nm. Dye uptake was expressed in micrograms of dye per specimen, whereby lower values indicated better effectiveness of the surface protector.

**Statistical analysis**

At the initial stage of statistical analysis, homogeneity of variances was first tested for normality. Due to the lack of variances, the Kruskal–Wallis test was used for data analysis. Further analyses were conducted with the Duncan test to highlight the significant differences between the groups.

**RESULTS**

Table 2 shows the comparison in dye uptake among the positive control specimens made from Vitremer, Ionomil U, and Dyrract AP. Statistically significant differences were seen among the three materials with Dyrract AP having the lowest dye uptake, followed by Ionomil U and Vitremer (p<0.0001).

Table 3 shows the results of multiple comparisons of surface protection for Ionomil U, Vitremer, and Dyrract AP. As seen in this table, the positive control groups for all the three restorative materials allowed the greatest dye penetration, significantly different from the other surface

<table>
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<tr>
<th>Table 2</th>
<th>Comparison of dye uptake with the positive control specimens from Vitremer, Ionomil U, and Dyrract AP</th>
</tr>
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<tbody>
<tr>
<td>Restorative Materials</td>
<td>n</td>
</tr>
<tr>
<td>Vitremer</td>
<td>18</td>
</tr>
<tr>
<td>Ionomil U</td>
<td>18</td>
</tr>
<tr>
<td>Dyrract AP</td>
<td>18</td>
</tr>
</tbody>
</table>

*Different letters indicate values that are significantly different at 0.0001% probability level (Duncan test).

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Results of multiple comparisons of surface protection for Ionomil U, Vitremer, and Dyrract AP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Protection</td>
<td>Ionomil U</td>
</tr>
<tr>
<td>n</td>
<td>Median (μg/specimen) Mean Rank*</td>
</tr>
<tr>
<td>Positive control</td>
<td>18</td>
</tr>
<tr>
<td>Adper single bond</td>
<td>18</td>
</tr>
<tr>
<td>Protect it</td>
<td>18</td>
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<tr>
<td>Finishing gloss</td>
<td>18</td>
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<tr>
<td>Nail varnish</td>
<td>18</td>
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<tr>
<td>LC varnish</td>
<td>18</td>
</tr>
<tr>
<td>Negative control</td>
<td>18</td>
</tr>
</tbody>
</table>

*Different letters indicate values that are significantly different at 0.0001% probability level (Duncan test).
treatments.

For Ionofil U, ranking from the highest to the lowest dye penetration values according to the applied surface treatment was as follows: Positive control, Adper Single Bond, Protect-It, Finishing Gloss, nail varnish, LC Varnish, and negative control. As indicated earlier, the positive control group presented a statistically higher dye uptake than the others ($x^2=97.013$, $p<0.0001$). In addition, the dye amounts for the specimens coated with Adper Single Bond were statistically higher than those of negative control specimens.

For Vitremer, ranking from the highest to the lowest dye penetration values was as follows: Positive control, Finishing Gloss, Adper Single Bond, Protect-It, nail varnish, LC Varnish, and negative control. Statistically, no differences in surface protection effectiveness were observed among the applied surface coating materials ($p>0.05$). However, the dye uptake of the coated specimens was statistically different from the negative and positive control specimens ($x^2=85.857$, $p<0.0001$).

For Dyract AP, ranking from the highest to the lowest dye penetration values was as follows: Positive control, Adper Single Bond, Protect-It, nail varnish, Finishing Gloss, LC Varnish, and negative control. The dye amounts for the positive and negative control specimens were statistically different from the other groups ($x^2=83.870$, $p<0.0001$).

**DISCUSSION**

The effect of water on the physical properties of restorative materials is the subject of many investigations. While some studies have reported negative effects on physical properties as a result of water storage and subsequent sorption\(^{17,19-20}\), Mitra\(^{20}\) has found no significant differences in properties immediately after curing and extended storage in water.

In our study, the hydration properties of conventional glass-ionomer cement and its hybrid versions were also investigated. It was found that resin-modified GIC, polyacid-modified composite resin, and conventional GIC specimens immersed in methylene blue (positive control) presented a significantly higher dye uptake. Further, it was determined that there were statistically significant differences in dye uptake among these materials. In particular, it was noted that the dye uptake amounts of Vitremer and Ionofil U were much higher than that of Dyract AP. These differences in findings could be attributed to the properties and amounts of resin, especially of hydrophilic resin\(^{7,26-38}\).

Theoretically, it was thought that activation by light or chemical inhibitors of glass ionomers might be effective against water sorption\(^{9}\). However, the addition of a photocurable capability did not significantly reduce glass-ionomer cements’ susceptibility to hydration. On the contrary, it has been reported that resin-modified GIC specimens absorbed considerable amounts of moisture when stored in either water or physiological saline solution\(^{21,25-27}\). Water sorption appeared to be dependent on the resin (HEMA) content\(^{22-25,30-32}\). Materials with higher hydrophilic resin (HEMA) content are therefore expected to have a higher water sorption property. This was confirmed by Li and co-workers\(^{30}\) who found that increased filler level in composite resins (i.e., lower resin content) resulted in lower water sorption.

The amount of hydrophilic resin (HEMA) in resin-modified GICs is approximately only 5%\(^{10}\). With this content, it behaves like a hydrogel. On the other hand, the network resulting from the copolymerization of acidic monomers and UDMA (urethane dimethacrylate) is less hydrophilic, such that the effect of water on Dyract AP was retarded\(^{29}\). These differences in the structures of restorative materials indicated that the hydration feature of Dyract AP was less than that of conventional and resin-modified GICs — and this observation also constituted one of the findings of the present study. However, when compared with the negative control group, it was seen that Dyract AP also absorbed dye significantly.

In a study by Cattani-Lorente et al.\(^{29}\), they compared the physical qualities of a resin-modified glass-ionomer cement kept in water against those of a polyacid-modified composite resin material. They found that the amount of water uptake in resin-modified glass-ionomer cement was higher and that it extended to a larger extent by behaving like a hydrogel.

In the same vein, van Dijken\(^{27}\) observed that non-protected Class III resin-modified GIC restorations showed the highest color change, surface degradation, and roughness compared with polyacid-modified composite resin and composite resin restorations. Besides, Beltrao et al.\(^{54}\) determined after a two-year clinical evaluation that while conventional Class III GIC restorations showed an improvement in esthetics, non-protected Class III resin-modified GIC restorations showed color change which could be caused by contamination during the residual acid-base reaction\(^{12}\).

In another study carried out to assess the water uptake of dental materials, Meyer et al.\(^{29}\) made a comparison among the conventional GIC, resin-modified GIC, and polyacid-modified composite resins. They determined that polyacid-modified composite resin absorbed less water than conventional GIC and resin-modified GIC, and that resin-modified GIC absorbed the largest amount of water. Likewise, they also attributed this result to the hydrophilic HEMA chains of the material.
Similar results found by Small et al. after a six-month storage in water further confirmed that conventional and resin-modified GICs exhibited a greater water uptake than the polyacid-modified composite resin, whereby water uptake was particularly rapid and higher for resin-modified GIC. These results were consistent with those of the present study.

It is noteworthy that both water uptake and water loss of restorative materials can compromise the physical properties of restorations. If water is lost due to desiccation, the reactions may stop and surface crazing may occur. If water is absorbed, the matrix will become chalky and erode rapidly. In relation to this, surface protection is necessary and recommended for these materials. The application of surface protection seems to preserve the water balance in the system and provide sufficient early protection to prevent water gain or loss from materials. Hotta and Hirukawa applied a bonding agent and a glazing agent on three restorative glass ionomers and investigated the water resistance of these two materials. They observed that the water resistance of glazing agent was better than that of bonding agent, but the bonding agent had a small advantage of preventing water movement over glass-ionomer cement. In another study by Hotta et al., it was found that light-cured bonding agent and glazing agent were more effective than Ketac varnish in decreasing water movement. However, they attributed this event to separating the varnish from the surface. In the same vein, Lutz and Phillips determined that not all light-activated resin bonding agents were successful in protecting the cement. These differences in findings could be attributed to variations in the physical and chemical properties of the resins.

In our study, the effectiveness of different surface protectors in preventing dye absorption was evaluated. Results for surface protectors combined with conventional GIC showed statistically significant differences in comparison with the positive control group. Further, Adper Single Bond absorbed significantly more dye compared to the negative control group. The results of our study agreed with those of previous studies.

As for the results of the surface protectors applied on Dyract AP, it was observed that LC Varnish absorbed the least dye and Adper Single Bond absorbed the most. When the same surface protectors were applied on Vitremer, no statistically significant differences in dye absorbing capacity were observed. However, when compared with either positive or negative control group, statistically significant differences were found. In another study by Cefaly et al., no significant differences in surface protection effectiveness were found for the Vitremer group when nail varnish, flexible resin, protective glaze, and proprietary glaze were applied on three different resin-modified glass-ionomer cements. On the other hand, in a research conducted by Ribeiro et al., Helibond light-activated bonding resin resulted in the least dye penetration whereas nail varnish resulted in the highest degree of dye penetration.

Results of the current study suggested that conventional GIC, resin-modified GIC, and polyacid-modified resin composite restorations could take up a considerable amount of dye, and that dye uptake decreased with the use of a protective coating for all of them.

A comparison of protected and non-protected restorations is indeed important to verify the real influence of surface protection toward restoration performance. Clinical studies are also necessary to compare the advantages of different protective agents over conventional GIC and its hybrid combinations. At this juncture, it must be highlighted that tooth brushing and dietary habits can influence the retention of these agents. Therefore, results obtained from clinical studies may differ from those obtained in our laboratory study.

REFERENCES

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