INTRODUCTION

Resin-based composite, polyacid-modified resin composite, and glass-ionomer cement materials are well-established cosmetic restorative materials that are used extensively in modern preventive and conservative dentistry. However, these materials may absorb significant amounts of water when exposed to aqueous environments.\(^1,2\)

There are two different mechanisms that occur when the previously mentioned dental restorative materials are exposed to or stored in water: the first is gaining weight from water uptake, and the second is losing weight from dissolution in water.\(^3\) The property of sorption indicates a combination of adsorption and absorption. Adsorption involves adherence of liquid molecules to the surface of a solid material. Absorption involves penetration of liquid molecules into the structure of the solid material, mainly through the process of diffusion.\(^4\)

Dental restorative materials are continuously in contact with fluids and saliva in the patient’s mouth. Consequently, the water sorption and solubility of these materials are of considerable importance. Fluid uptake into resin-based materials may have both beneficial and detrimental consequences.\(^5\) Hygroscopic expansion, which is caused by water uptake, may relieve the residual stresses of resin-based composite materials during polymerization shrinkage and may also reduce interfacial gap width with a corresponding microleakage reduction.\(^5-8\) On the other hand, fluid sorption may lead to discoloration and act as a plasticizer, leading to deterioration of physical/mechanical properties and decreasing the life of these materials, and reducing their bonding to tooth structure.\(^9,10\)

Glass-ionomer cements also are widely used in clinical dentistry. They are water-based materials that consist of special ion-leachable glass and water-soluble polymeric acids, and set by an acid-base reaction in the presence of water. Conventional and resin-modified glass-ionomer cements absorb water and may dissolve by surface wash-off, diffusion of water through pores and cracks in the cement, and diffusion from the bulk of the cement.\(^5,11\) The purpose of this study was to

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Key words: Sorption, desorption, material loss, tooth-colored

ABSTRACT

The objective was to evaluate the sorption, desorption and material net loss for different direct tooth-colored restorative materials. Six different direct tooth-colored restorative materials (Z-100, Glacier, Wave, Ketac-Molar, Vitremer, and Compoglass F) were used. Thirty-six disk-shaped specimens (6/material) were fabricated in a cylindrical rubber mold (15 mm × 2 mm). The specimens were subjected to sorption, and desorption cycles, and the percentage values of sorption, desorption, and material net loss calculated. Data were analyzed using a one-way ANOVA and Post hoc Tukey’s multiple comparison tests (\(\alpha = 0.05\)). The results of sorption and desorption showed that the least changes were for Glacier and the most changes were for Ketac-Molar. If it is assumed that sorption would influence the staining of restorations then Ketac-Molar would be the most susceptible while Glacier would be the least. The solubility, based on the amount of material lost, appeared highest for Ketac-Molar and lowest for Z-100 and Vitremer.

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evaluate the water sorption, desorption and material net loss for different types of direct tooth-colored restorative materials.

METHODOLOGY

Specimen Fabrication

Six direct tooth-colored restorative materials were assessed (Table 1). Thirty-six disk-shaped specimens (6/material) were fabricated in a cylindrical rubber mold (15 mm × 2 mm). Specimens were fabricated according to the manufacturers’ instructions. Each specimen in the rubber mold was placed, covered with Mylar strips and pressed between two glass plates. The photo-cure specimens were exposed to light for 60 s on each side using a halogen light (Elipar® Highlight, 3M ESPE, St. Paul, MN, USA), at 400 mW/cm² that were verified with a Model 100 Curing Radiometer. The chemical-cure specimens were allowed to cure for 5 min. All the specimens were gently polished using wet medium, fine and ultrafine Sof-Lex (3M ESPE) polishing disks with a slow-speed handpiece. Z-100 resin-based composite material was used as a control material.

Desiccation Procedure

All specimens except those of Ketac-Molar were subjected to drying. Specimens were weighed and then placed in a desiccator at 37°C for 24 h, removed to a similar desiccator at room temperature for 1 h, then weighed with a precision balance (Precisa 180A, Micro Precision Calibration Inc., Grass Valley, CA, USA). This cycle was repeated until the change in weight was not more than 0.2 mg in any 24-hour period. Ketac-Molar specimens were stored in a small container without water at room temperature and the entire container was wrapped with wet paper towels.

Sorption and Desorption Procedure

All specimens including those of Ketac-Molar were placed in distilled water at 37°C for 15 d and weighed at specified times. An individual specimen was removed from the water and lightly blotted with a paper towel until no visible moisture was observed. The weight measurements were performed as before to an accuracy of 0.1 mg. The weights were recorded every 30 min for the first 4 h, then every hour for the next 4 h, and then once a day for the next 14 d.

All the specimens were removed from the water and placed in an oven at 37°C for 15 d. The weights were recorded again at the same time intervals as described previously.

Sorption, desorption, and material net loss percentages were calculated as follows:

\[
\text{Sorption} = \frac{W_s - W_o}{W_o} \times 100\%
\]

\[
\text{Desorption} = \frac{W_d - W_o}{W_o} \times 100\%
\]

Material net loss = \[
\frac{W_t - W_o}{W_o} \times 100\%
\]

<table>
<thead>
<tr>
<th>Material</th>
<th>Type</th>
<th>Manufacturer</th>
<th>Curing Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z-100</td>
<td>Highly filled Resin</td>
<td>3M ESPE, St. Paul, MN, USA</td>
<td>Photo-cure</td>
</tr>
<tr>
<td></td>
<td>Composite</td>
<td></td>
<td></td>
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<tr>
<td>Glacier</td>
<td>“Condensable” Resin</td>
<td>Southern Dental Industries, Melbourne, Australia</td>
<td>Photo-cure</td>
</tr>
<tr>
<td></td>
<td>Composite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave</td>
<td>Flowable Resin</td>
<td>Southern Dental Industries, Melbourne, Australia</td>
<td>Photo-cure</td>
</tr>
<tr>
<td></td>
<td>Composite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ketac-Molar</td>
<td>Conventional Glass-ionomer</td>
<td>3M ESPE, St. Paul, MN, USA</td>
<td>Chemical</td>
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<tr>
<td>Aplicap</td>
<td></td>
<td></td>
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<tr>
<td>Vitremer</td>
<td>Resin-modified Glass-ionomer</td>
<td>3M ESPE, St. Paul, MN, USA</td>
<td>Photo-cure</td>
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<tr>
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<tr>
<td>Compoglass F</td>
<td>Polyacid-modified</td>
<td>Vivadent, Schaan, Liechenstein</td>
<td>Photo-cure</td>
</tr>
<tr>
<td></td>
<td>Resin Composite</td>
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<td></td>
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</tbody>
</table>
Where, $W_0 =$ weight after desiccation, $W_s =$ weight after 15-day immersing in water, $W_d =$ weight after 15-day placing in an oven at 37°C. All readings were done by one investigator and verified independently by the other one.

**Statistical Analysis**

Statistical analyses were carried out using SPSS statistical software (v16, SPSS Inc., Chicago, IL, USA). Data were submitted to a one-way ANOVA and Post hoc Tukey’s multiple comparison tests with the probability for statistical significance set at $\alpha = 0.05$.

**RESULTS**

The means of the percentage values for sorption, desorption, and material net loss of the six different types of direct tooth-colored materials are presented in Table 2 and illustrated in Figure 1.

During sorption, Glacier and Ketac-Molar showed respectively, significantly lower and significantly greater percentage increases in weight ($p<0.02$). The percentage increases in weights of Z-100, Wave, Vitremer and Compoglass F were almost similar, without any significant differences among them.

**TABLE 2: MEANS (STANDARD DEVIATIONS) OF PERCENTAGE VALUES FOR SORPTION, DESORPTION, AND MATERIAL NET LOSS OF DIFFERENT DIRECT TOOTH-COLORED RESTORATIVE MATERIALS**

<table>
<thead>
<tr>
<th>Material (N = 6 each)</th>
<th>Sorption Mean (SD)</th>
<th>Desorption Mean (SD)</th>
<th>Material Net loss Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z-100</td>
<td>0.71 (0.06)</td>
<td>0.76 (0.05)</td>
<td>-0.01 (0.07)</td>
</tr>
<tr>
<td>Glacier</td>
<td>0.39 (0.09)</td>
<td>0.59 (0.06)</td>
<td>0.21 (0.12)</td>
</tr>
<tr>
<td>Wave</td>
<td>0.63 (0.10)</td>
<td>0.87 (0.10)</td>
<td>0.26 (0.07)</td>
</tr>
<tr>
<td>Ketac-Molar</td>
<td>10.70 (1.70)</td>
<td>10.70 (1.70)</td>
<td>1.42 (0.03)</td>
</tr>
<tr>
<td>Vitremer</td>
<td>0.72 (0.40)</td>
<td>2.16 (0.40)</td>
<td>-0.51 (0.38)</td>
</tr>
<tr>
<td>Compoglass F</td>
<td>0.70 (0.11)</td>
<td>0.91 (0.08)</td>
<td>0.19 (0.11)</td>
</tr>
</tbody>
</table>

In each column, means with the superscript letter $^a$ are not statistically different.

Fig 1: Sorption, desorption and material net loss of different direct tooth-colored restorative materials
During desorption, Glacier showed a significantly smaller percentage loss in weight than the other materials, while Viteremer and Ketac-Molar showed significantly greater percentage losses in weight than the other materials (p<0.01). The percentages of weight losses for Z-100, Wave and Compoglass F were almost similar, without any significant difference among them.

Regarding the percentages of net weight losses of materials during the cycles of water sorption and desorption, Ketac-Molar showed the largest percentage net weight loss (p<0.01). On the other hand, after desorption Z-100 and Viteremer actually retained some of the weight gained during the water sorption procedure (-0.01% and -0.51%, respectively). The percentage net weight losses of Glacier, Wave and Compoglass F were almost similar.

**DISCUSSION**

Water molecules are able to diffuse through the inter-chain spaces of the resin matrix because of their smaller size of radius, which is less than 0.158 nm and smaller than the inter-chain spaces.12

According to the mean of water sorption percentages (Table 2) three resin-based composite restorative materials could be ranked from high to low; Z-100 (0.70%) > Wave (0.63%) > Glacier (0.39%). This finding might be due to the differences in the resin-based matrix polymers used in these resin-based composite materials; urethane dimethacrylate (UDMA) in Glacier and Wave, and bisphenol A-glycidyl methacrylate (Bis-GMA) in Z-100. Polymers made with the UDMA monomers exhibit less water sorption than those prepared from Bis-GMA.13

For the same groups of resin-based matrix, the water sorption may also depend on the material’s filler content.4,14 Glacier is a so-called “condensable” material with the greatest proportion of fillers (62% by volume), and Wave is a flowable composite with the smallest proportion of fillers (50% by volume), the proportions being inversely related to their water sorption findings. The higher percentage of water sorption of Z-100 when compared to Glacier and Wave might have been related to porosities or air voids in the specimens caused by the high polymerization shrinkage of Z-100.15

The water desorption percentages of the resin-based composite materials also could be ranked from high to low; Wave (0.87%) > Z-100 (0.76%) > Glacier (0.59%). The higher desorption of Wave material when compared to Z-100 and Glacier might be related to the lower filler content and higher polymer matrix in Wave, which may lead to more hydrolytic degradation of the polymer matrix during the water sorption process.

Ketac-Molar glass-ionomer cement displayed the highest mean sorption and desorption values of all materials tested (10.70% and 10.70%, respectively). Ketac-molar is a conventional glass-ionomer that absorbs water necessary for the acid-base setting reaction and for ionic crosslinking.16 There are two modes for water diffusion into the bulk of these cements: via micro-voids and by binding to hydrophilic groups.17 Glass-ionomers are susceptible to water loss before full maturation. The bound water loss was found to be much less than for the unbound type, and for that latter reason loss of water during the desorption process was the highest for Ketac-Molar when compared to the other five tested materials.11 Ketac-Molar also lost the greatest amount of material at the end of the experiment (1.42%), which indicated a considerably greater level of solubility.

Vitremer and Compoglass F showed similar mean sorption values (0.72% and 0.70%, respectively) without any significant differences when compared to Z-100 and Wave, but significantly higher than Glacier and lower than Ketac-Molar (Table 2). Vitremer is a resin-modified glass-ionomer cement, which has a dual setting reaction involving mainly the acid-base reaction of a conventional glass-ionomer and the free radical polymerization of a resin composite.18 The absorption of water by Vitremer is important to complete the acid-base reaction and is assisted by the presence of hydrophilic constituents such as hydroxylethylmethacrylate (HEMA). The percentage absorption of water by the resin-modified glass-ionomer Vitmer was less than by the conventional glass-ionomer Ketac-Molar because the latter is a purely acid-base setting reaction. Compoglass F is as polyacid-modified resin-based composite “compomer”. In compomer materials the acid-base reaction is initially limited because of the anhydrous structure, but once water is absorbed then a belated acid-base reaction is likely to happen.19

Restorations in clinical situations are also subjected to masticatory and tooth-brushing stresses.
These may produce greater amounts of material loss than indicated in the present study where the specimens were simply immersed in water without any agitation. A future study will evaluate other physical properties after specimen immersion in water and artificial saliva, and other novel materials will be included.

CONCLUSION

Within the limitations of this laboratory study and small sample sizes we found that:

- If it is assumed that sorption would influence the staining of restorations then Ketac-Molar would be most susceptible while Glacier would be least susceptible.
- Solubility, based on the amount of material lost, was the highest for Ketac-Molar and the lowest for Z-100 and Vitremer.

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REFERENCES