An evaluation of water absorption of Giomer in comparison to other resin-based restorative materials

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ABSTRACT

Background: Polymeric composites have been widely used as dental restorative materials. A fundamental knowledge and understanding of the behavior of these materials in the oral cavity is essential to improve their properties and performance. The goal of this study was to measure water sorption of four composite resins containing different filler and resin matrix contents.

Materials and method: Resin composite specimens giomer (Beautifil II), Filtek™ P90, Filtek™ Z350 XT, and Tetric N-Ceram were prepared in a cylindrical mould of 3mm thickness and 6mm diameter (n=10) and light cured. All specimens placed in silica-gel desiccators at 37°C for seven days, a constant weight was obtained. All samples were immersed in deionized distilled water at 37°C and weighed at suitable time interval once a week for 30 days. Water sorption was calculated based on ISO 4049. Data were subjected to student t-test.

Results: Silorane and Giomer composites showed the lowest values of water sorption, while Z350 and Tetric N-Ceram displayed the highest values at a period of 4 weeks.

Conclusion: Each resin-matrix composite varied in water sorption which may affect clinical service. The attained water sorption values are mainly influenced by the generic type of material and variations occurring between materials of the same type may result from differences in resin matrix compositions.

Keywords: Water sorption, Giomer, dental resin, silorane.

INTRODUCTION

Restorative dental composites are becoming more popular and extensively used in dentistry due to their esthetic and good in physical and mechanical properties. However, in a wet oral environment the composites may absorb water or other liquids such as saliva, food components or beverages which can have an appreciable influence on the degradation of dental composite. Excessive of liquids uptake may produce deleterious effects on the structure and function of the resin, as these can reduce the mechanical and physical properties that lead to a shortened service life of dental restoration. ISO 4049 is a standard method which is commonly used by researchers to determine water sorption and solubility of restorative dental composites (1).

In an aqueous oral environment, polymer composites absorb water and release unreacted monomers. The release of unpolymerized monomers from polymer composites may stimulate the growth of bacteria around the restoration and promote allergic reactions in some patients. Also the water ingress into dental composites in the oral cavity can, over time, lead to deterioration of the physical/mechanical properties due to hydrolytic breakdown of the bond between the silane-filler particles, filler matrix debonding or even hydrolytic degradation of the fillers.

However, some water ingress may have a positive side effect, such as the expansion of the composite compensating for polymerization shrinkage leading to improved marginal sealing. Thus the solvent uptake by dental composite is generally a very important property which must be investigated (2).

Giomers, a new class of materials in which the glass is pre-reacted with polyacid then blended with resin to form a composite-type structure. The pre-reacted zone may affect only the surface of the glass or may consume almost the whole of the glass particles and this difference creates a further sub-division of the products. Giomer bear the advantages of both composite resin and glass ionomers, they have excellent esthetics, good polishability, and biocompatibility and also render glass ionomer properties, including fluoride release and fluoride recharge potential. Proper seal against bacterial microleakage and minimal mechanical and chemical irritation of the pulp are other advantages of Giomers (3).

This study emphasized in determination of water storage on water sorption of 4 different types of composite resin materials.

MATERIALS AND METHOD

Forty disk shape specimens of Giomer (Beautifil II, Shofu), Filtek™ P90 (3M ESPE,USA), Filtek™ Z350 XT (3M ESPE,USA), and Tetric N-Ceram (Ivoclar Vivadent, Liechtenstein) of (6mm internal diameter and 3 mm height) shade A3 were fabricated using a
specially designed cylindrical mold (6mm diameter and 3mm depth). A transparent matrix strip covered with a glass slide of 1mm in thickness was applied at the top of the surface of each composite sample with a constant pressure to extrude excess material, to flatten the surface and to reduce voids at the surface. All specimens were light cured for 40 seconds using LED light curing device with a light intensity of 500mW/cm² according to manufacturer instructions. Specimens cured under the glass slide had a mirror smooth surface that didn’t require further finishing and polishing (1). The specimen was carefully removed from the mould and flash cut away using a sharp blade (1).

All samples were transferred to a desiccator with silica gel maintained at 37°C, where they were kept for seven days until weight loss change stabilized. Constant weight was obtained with an accuracy of 0.0001g using calibrated electronic microbalance (Sortorious_Germany) (5).

The specimens were then individually placed in a sealed plastic container containing about 10 ml of deionized distilled water in incubator at 37°C. The media used were changed twice a week (48 hours) after incubation and continue as one measurement every week for 30 days. Prior to weighing, the specimens were removed, blotted dry to remove excess liquid, weighed and returned to the liquid bath (6).

The percentage weight changes were calculated using the following formula:

\[
\text{Weight change} = \frac{WA - WB}{WB} \times 100 \%
\]

Where WA is the weight of the sample after immersion and WB is the original weight of the sample before immersion.

**RESULTS**

The mean, standard deviation and standard error of water sorption for all groups are illustrated in table (1).

All disk specimens exhibited percentage mass changes as a function of time when immersed in de-ionized water. Statistical analysis of data using t-test between Giomer and Silorane groups showed that there was a significant difference in water sorption at 1 week, 2 weeks and 3 weeks of immersion in water p<0.05, while there was no significant difference at 4 weeks immersion in water p>0.05 table (2).

There was a significant difference in water sorption between Giomer and Tetric N-Ceram after one week immersion in water p<0.05, while there was no significant difference between the two materials after 2 weeks, 3 weeks, and 4 weeks immersion in water p>0.05 table (3).

Student t-test also showed that there was no significant difference in water sorption between Giomer and Z350 after 1 week, 2 weeks, and 3 weeks immersion in water p>0.05, while there was a significant difference between the two materials after 4 weeks immersion in water p<0.05 table (4).

**DISCUSSION**

There are several factors that influence water sorption, for instance the hydrophilicity of the polymer matrix, crosslinking density, fillers, porosity and solvents (7). Water molecules induce the degradation of composites via two mechanisms. Firstly, water molecules diffuse into the polymer network and occupy the free volume between polymer chains and microvoids, causing plasticization and swelling of polymer matrix and also initiate the chains scission causing monomer elution. The water molecules also tend to degrade the siloxane bonds (bond between silanol groups of the silica surface and the silane coupling agent) via a hydrolysis reaction, causing filler debonding (1). These occurrences lead to the degradation or softening of resin composites which may diminish some physical and mechanical properties such as hardness, strength and modulus of elasticity. Thus the dimensional change of a polymer composite in a solvent is complex and difficult to predict and depends on the chemical structure of the polymer matrix. Several data for water sorption for composite materials have been published, but it is difficult to correlate them as the results are often for different time periods and are expressed in different units. Moreover comparisons are difficult to make due to differences in reported specimen size, since different sizes of specimen will take different periods of time for water to completely infiltrate throughout the polymer matrix. The smaller the specimens, the shorter the period for equilibration with water, and the materials which absorbed more water also took longer to stabilize (8).

Results of the present study reported that Silorane was found to have statistically the lowest water sorption among the test materials. Silorane is a new monomer with the combination of hydrophobic siloxane and low shrinkage ring-opening oxirane. Its photo-activated cationic polymerization is relatively intensive than with radical polymerization to oxygen. Not only is the polymerization shrinkage reduced, but also this effect increases the degree of conversion. Thus, the water sorption of Silorane will be expected to be low (9).
Giomer showed statistically lower water sorption than Tetric N-Ceram and Z350, this may be due to the incorporation of higher amount of fillers into polymer matrix of Giomer, this can reduce the available free volume for water uptake that lowers the rate of water sorption. It is generally understood that highly filled composites are more resistant to degradative reactions, based on more limited spaces and pathways available for water molecules to diffuse within the polymer structure (7).

The main difference in microstructure between Giomer and the other tested composite materials is the presence of pre-reacted glass polyacid zones which become part of the filler in the Giomer structure (10).

Results of this study also revealed that Z350 showed higher water sorption than giomer, this may be attributed to the porous nature of zirconia and silica nanocluster, in addition, non-agglomerated nanosilica in Z350 could also provide a large surface area to volume ratio, which allows the fluids accumulated around the filler-polymer interface and leads to an increase in the water sorption. It could be stressed that the total mass of water absorbed was not only diffused through the polymer matrix but also largely diffused into the filler-matrix interface or microvoids of the composite (9). Z350 also contains comparatively small nanoclusters, producing a greater surface area to volume ratio and hence a larger area of hydrophilic silane available for water sorption. Consequently, the physical-chemical properties of the intermediate phase will become more critical since a higher degree of silanisation will be required for resin-based composite with a high volume percentage of nanoparticles (11). Z350 contains hydrophilic monomers which have the following order in hydrophilicity: TEGDMA > BisGMA > UDMA. Mohsen et al., suggested a mechanism of water sorption in UDMA polymer and composite. At an early stage, strongly bound water will form intramolecular hydrogen bonds with the UDMA polymer. Progressively, loosely bound water will interact with intermolecular hydrogen bonds of adjacent polymer chains, inducing chain slippage and polymer plasticization (2).

Tetric N-Ceram showed statistically higher water sorption than Giomer but the difference is statistically not significant, because the monomers in these materials are hydrophilic in nature due to the presence of polar groups in their structure which tends to be attracted by water molecules to form hydrogen bonding. Nevertheless, the degree of hydrophilicity of monomers varies, depending on the type of functional groups obtained in monomer structure. The hydroxyl group present in BisGMA would form a strong hydrogen bonding with water molecules (13).

The high viscosity of Bis-GMA polymer requires the addition of diluents monomers, such as TEGDMA. Such diluents monomers, coupled with the presence of hydroxyl groups in the BisGMA molecules, result in an increase in water sorption because TEGDMA polymer have high network flexibility and heterogeneity creating spaces which accommodate a larger amount of water (14).

As conclusion, within the limitation of this study, it has been shown that resin-composite specimens investigated were found to undergo progressive water sorption over a period of 4 weeks. A Silorane composite, however, showed statistically the greatest stability in an aqueous environment followed by Giomer restorative material. By contrast, Z350 and Tetric N-Ceram was the least stable material, due to the incorporation of hydrophilic monomers.

REFERENCES


Table 1: Descriptive statistics of water sorption values for all groups

<table>
<thead>
<tr>
<th>Material</th>
<th>1 week Mean (g/cm³)</th>
<th>1 week SD</th>
<th>1 week SE</th>
<th>2 weeks Mean</th>
<th>2 weeks SD</th>
<th>2 weeks SE</th>
<th>3 weeks Mean</th>
<th>3 weeks SD</th>
<th>3 weeks SE</th>
<th>4 weeks Mean</th>
<th>4 weeks SD</th>
<th>4 weeks SE</th>
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<tbody>
<tr>
<td>Silorane</td>
<td>0.001583</td>
<td>0.000953</td>
<td>0.000302</td>
<td>0.00608</td>
<td>0.001625</td>
<td>0.000514</td>
<td>0.00709</td>
<td>0.001383</td>
<td>0.000438</td>
<td>0.00816</td>
<td>0.001583</td>
<td>0.000501</td>
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<tr>
<td>Giomer</td>
<td>0.0041</td>
<td>0.003351</td>
<td>0.001061</td>
<td>0.00865</td>
<td>0.002321</td>
<td>0.000734</td>
<td>0.00909</td>
<td>0.002315</td>
<td>0.000753</td>
<td>0.01125</td>
<td>0.003446</td>
<td>0.001091</td>
</tr>
<tr>
<td>Tetric N-Ceram</td>
<td>0.01169</td>
<td>0.006054</td>
<td>0.002031</td>
<td>0.0114</td>
<td>0.005967</td>
<td>0.001255</td>
<td>0.01192</td>
<td>0.004128</td>
<td>0.001306</td>
<td>0.01268</td>
<td>0.003446</td>
<td>0.001355</td>
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<tr>
<td>Z 350</td>
<td>0.00658</td>
<td>0.001994</td>
<td>0.000631</td>
<td>0.01229</td>
<td>0.003509</td>
<td>0.001417</td>
<td>0.01477</td>
<td>0.004094</td>
<td>0.001296</td>
<td>0.01740</td>
<td>0.005852</td>
<td>0.001852</td>
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</table>

Table 2: Student t-test between Giomer and Silorane groups at specified times

<table>
<thead>
<tr>
<th>Material</th>
<th>Time</th>
<th>t-test</th>
<th>p-value</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giomer &amp; Silorane</td>
<td>1 week</td>
<td>4.542</td>
<td>0.001</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>2 weeks</td>
<td>3.114</td>
<td>0.012</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>3 weeks</td>
<td>3.888</td>
<td>0.004</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>4 weeks</td>
<td>1.129</td>
<td>0.288</td>
<td>NS</td>
</tr>
</tbody>
</table>

P<0.05 Significant
P>0.05 Non significant

Table 3: Student t-test between Giomer and Tetric N-Ceram groups at specified times

<table>
<thead>
<tr>
<th>Material</th>
<th>Time</th>
<th>t-test</th>
<th>p-value</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giomer &amp; Tetric N-Ceram</td>
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<td>2.088</td>
<td>0.049</td>
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<td></td>
<td>2 weeks</td>
<td>1.286</td>
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<td>3 weeks</td>
<td>0.893</td>
<td>0.395</td>
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<td></td>
<td>4 weeks</td>
<td>0.411</td>
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Table 4: Student t-test between Giomer and Z350 groups at specified times

<table>
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<th>Material</th>
<th>Time</th>
<th>t-test</th>
<th>p-value</th>
<th>Sig</th>
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<td></td>
<td>4 weeks</td>
<td>0.411</td>
<td>0.690</td>
<td>S</td>
</tr>
</tbody>
</table>

Figure 1: Bar chart showing means of water sorption values for Silorane, Giomer, Tetric N-Ceram, and Z350 materials after 1, 2, 3, and 4 weeks immersion in water