Short Term Sorption Effect on three Esthetic Dental Filling Materials in Various Media

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ABSTRACT

Aim: This study measures the weight gain of three esthetic restorative materials after immersion in water, Coke and Fanta for 120 hours.

Materials and Methods: Three restorative materials (Visible Light Cure Composite; Prime Dental INC USA, GC Fuji IX GP; GC Corporation Japan, Amalgomer® CR; Advanced HealthCare LTD, UK) and three immersion media (Distilled water, Coca-Cola; Nigeria Bottling Company LTD, Fanta; Nigeria Bottling company LTD) were used. A mold of 10 mm in diameter and 4 mm depth was constructed to form blocks. At different times, the materials were manipulated and placed into the mold using a plastic instrument. Fuji IX and Amalgomer CR were chemical cure materials, therefore they were left to polymerize in the mold. Composite was photopolymerized for 1 minute, and the specimens were removed after 24 hours. Three blocks of each test material were weighed thrice using calibrated electronic microbalance. The materials were immersed in either of the three

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solutions for 120 hrs; retrieved, dried and weighed thrice using the same digital weighing balance. Data was recorded in study-specific charts.

**Results:** All the materials gained weight after immersion for 120 hours in the three media. In water and Coke, Fuji IX gained the least weight of 24.7% and 19.5% respectively. Composite gained the least weight of 20.7% in Fanta. Amalgomer gained the largest weight of 27.2%, 26.2% and 29.2% in water, Coke and Fanta respectively. Cumulatively, Amalgomer gained the most weight (34.2%) in the three media and Fuji IX the least (32.5%). Water caused the greatest weight gain of 33.9% in the three materials while Fanta caused the least increase of 33%.

**Conclusion:** All the materials gained weight after 120 hours. This revealed a tendency for all of them to absorb fluid from their environment. There is need for caution in their application in less than optimum conditions. Continuous improvement in the properties of these materials is warranted.

**Keywords:** Restorative materials; esthetic; water sorption; weight gain.

1. **INTRODUCTION**

Due to several disadvantages of amalgam, restorative materials which are esthetic and allow only minimal removal of tooth structure like composite and glass ionomer cements (GIC) and their varieties came into focus. Also patients’ preference for these materials gave more impetus to clinical and laboratory researches concerning them.

Composite restorative materials have been shown to have good aesthetics with good clinical performance. It is relatively durable with good mechanical properties. It has undergone several developments such that it has widespread clinical applications, widely accepted for mostly all types of cavities and especially in the restoration of posterior carious lesion.

GIC on the other hand is well known for its caries inhibitory (fluoride leaching) effect and ability to bond chemically to tooth structure [1,2]. However, its poor mechanical properties such as low fracture strength, low toughness and wear limit its extensive use in dentistry as a filling material in stress bearing areas [1]. Based on these inherent weaknesses of GIC, many modifications have been made to improve on the physical properties of the conventional GIC to satisfy the recommendations of a posterior restorative material for adult tooth. These include incorporating small metallic particles into the glass to produce cermets [3], while ‘miracle mixture’ was developed by incorporating amalgam alloy powder into glass ionomer cements [4]. Furthermore, highly viscous GIC (Fuji IX) was developed and it is routinely used in Atraumatic Restorative Technique (ART) and intermediate to long term temporary restorative materials [5-7].

A more recent development was the incorporation of ceramics into GIC producing a material with mechanical strength approximating that of amalgam. Amalgomer™ CR, a ceramic reinforced posterior GIC is said to possess compressive, flexural and tensile strength approximating that of amalgam [8-10].

In addition to these, it is said to have a sustained high level of fluoride release, superior radiopacity, and superb aesthetics. Even with the addition of ceramic, it still retains its ability to bond chemically to tooth structure and it has good working time. The material is also said to be free of shrinkage, expansion, corrosion and lacks thermal conductivity which is a major problem associated with some other restorative materials. Moreover, it is said to have excellent wear characteristics [8].

Two important physical properties that influence the clinical durability of a restorative material are water sorption and solubility of the material. Water sorption can increase the volume of the material and it can act as a plasticizer and cause deterioration of the matrix structure of the material [11]. The water sorption and solubility of dental restorative materials are of considerable clinical importance and cannot be neglected [12].

Materials which are placed for long periods in oral environment will undergo an interaction with oral fluids. This interaction may involve dissolution or degradation of surface layers whilst in others the interaction may involve a leaching out of unbound or loosely bound components or an uptake of fluids into the structure of materials [13].

During their service years, restorative materials bathe in various fluids and solutions. In the light
of this, the present study was conducted to evaluate the water sorption of Composite (Prime Dent micro-hybrid), Fuji IX and Amalgomer CR in three direct solutions; distill water, Coke and Fanta

2. MATERIALS AND METHODS

This experimental study was carried out in the Material Engineering laboratory of the Obafemi Awolowo University, Ile-Ife, Nigeria. Three direct esthetic dental restorative materials (Visible Light Cure Composite; Prime Dental INC USA, GC Fuji IX GP; GC Corporation Japan, Amalgomer™ CR; Advanced HealthCare LTD, UK) and three drinks (Distilled water, Coca cola; Nigeria Bottling Company LTD, Fanta; Nigeria Bottling company LTD) were used. The drinks were selected based on their popularity, availability and use. This was done after convenience sample of 25 adults were asked to list what they used to quench their thirst and their most popular leisure drinks that are readily available. Their responses were thereafter imputed into an Excel sheet and the frequencies generated. The first three drinks listed were noted. The distill water was obtained from the lab and the two soft drinks (Coke and Fanta) were purchased from retailers.

A plastic saucer-shaped mold of 10 mm in diameter and 4 mm depth was constructed to form saucer shaped blocks of the restorative materials (Fig. 1). The mold was sparingly lubricated with petroleum jelly to facilitate removal of the materials after setting. The materials were handled according to the manufacturer’s instruction.

excess material, remove voids and produce a flat surface [14].

Fuji IX and Amalgomer CR were chemical cure materials, therefore they were left to polymerize in the mold. Composite resin material was then photopolymerized using light curing unit by applying the tip of the light probe directly against the transparent strip and also through the plastic mold to ensure adequate polymerization. Light activation was carried out for 1 minute, and then the specimen was removed from the mold after 24 hours by applying light finger pressure.

Three blocks were made of each test material. All specimens were placed in a silica-gel desiccator for 48 hours to ensure that the material would contract to a maximum capacity. Then the samples were weighed thrice using digital weighing microbalance (Mettler Toledo, Switzerland) (Fig. 2), the readings were recorded to the nearest 0.000001 g.

The specimen of each material was immersed in 50 ml of either distilled water, Coke or Fanta contained in a beaker at room temperature (25°C). The beakers containing the test materials were cork covered and left in the solution for 120 hrs, and then retrieved.

Prior to weighing, the specimens were taken out, gently dried with blotting paper and left undisturbed for 4 minutes in order to allow stabilization of each specimen [14]. Each of them were weighed thrice again using the same digital weighing balance. The specimen molds were labeled with Arabic numbers prior to their delivery to the laboratory. Data was recorded in
study-specific charts and authenticated before it was retrieved by the authors. The percentage weight changes were calculated using the following formula:

\[
\text{Weight change} = \frac{W_a - W_b}{W_a} \times 100\%
\]

Where \( W_a \) is the weight of the sample before immersion and \( W_b \) is the weight of the sample after immersion. Paired samples T-Test was used to check if there is any significant difference between original weights and the weights after immersion. Significant difference was set at (\( P < 0.05 \)).

3. RESULTS

Table 2 shows that all the evaluated restorative materials, composite, Fuji IX and Amalgomer CR gained weight after immersion for 120 hours in the 3 media (Water, Coke and Fanta). Paired samples T-Test shows that the weight gain by the materials in all the media (difference between weight after immersion and weight before immersion) were statistically significant (\( p<0.05 \)).

The highest percentage weight gain of 29.2% occurred in the immersion of Amalgomer in Fanta while the least was 19.5% which occurred in Fuji IX in Coke.

Table 3 shows that when the materials were immersed in water, Fuji IX gained the least weight of 24.7% and Amalgomer gained the most weight of 27.2%. In Coke, Fuji IX also gained the least weight of 19.5% while Amalgomer gained the largest weight of 26.9%. In Fanta, Composite gained the least weight of 20.7% while Amalgomer gained the largest weight of 29.2%.

Amalgomer cumulatively gained the most weight of 34.2% in the three media, next is Composite (33.3%) and Fuji IX the least (32.5%). Water showed a tendency to cause the greatest weight gain of 33.9% in the three restorative materials, Coke 33.1% while Fanta caused the least increase of 33%.

4. DISCUSSION

Saliva is found in the oral environment. It is a diluted fluid comprising more than 99% water and dissolved inorganic and organic solids. This prompted the use of water to evaluate the weight gain of three restorative materials. In the oral cavity, apart from saliva, the restorative fillings birth in various dietary solutions such as water, carbonated drinks and juices, tea, coffee and even wines during their service years. This prompted the use of the 2 most popular drinks in our environment in addition to water as the test solutions.

Table 1. Composition and manufactures of test restorative materials and immersion media

<table>
<thead>
<tr>
<th>Restorative material</th>
<th>Lot no.</th>
<th>Composition</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>GC Fuji IX GP</td>
<td>1208231</td>
<td>Powder: Fluoro Aluminosilicate glass, Liquid: Polyacrylic Acid,</td>
<td>GC corporation, Tokyo, Japan</td>
</tr>
<tr>
<td>Amalgomer™ CR Technology</td>
<td>011114-4</td>
<td>Glass polyalkenoate</td>
<td>Advanced Health Care, TN11 8JU, UK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ceramic reinforced</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water mix formula</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Classes 4.26 &amp; 4.2c</td>
<td></td>
</tr>
<tr>
<td>Prime Dent Visible light cure composite (Micro-Hybrid)</td>
<td>NKC27P</td>
<td>7ml VLC One step dentine bonding</td>
<td>Prime Dent® Manufacturing INC USA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7ml VLC Surface Sealant</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4gm S.F. Etchant Gel (37 % phosphoric acid)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resin-Based Micro-Hybrid Composite</td>
<td></td>
</tr>
</tbody>
</table>

Immersion Solutions

<table>
<thead>
<tr>
<th>Immersion Solutions</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fanta</td>
<td>Carbonated water, Sugar, Acidulants (citric acid), Stabilisers (E414, E415), Preservative (Sodium Benzoate), Orange flavor, Colourants (Sunset yellow, tartrazine), antioxidant.</td>
<td>Nigeria Bottling Company LTD. Nigeria</td>
</tr>
<tr>
<td>Coke</td>
<td>Carbonated water, Sugar, Colour (caramel), Acidulant (Phosphoric acid), Cola flavor and Caffeine</td>
<td>Nigeria Bottling Company LTD. Nigeria</td>
</tr>
</tbody>
</table>
Table 2. Differences in weight before and after immersion of the restorative materials and the percentage weight change

<table>
<thead>
<tr>
<th>Restorative material</th>
<th>Solution</th>
<th>Weight before immersion (µg)</th>
<th>Weight after immersion (µg)</th>
<th>Mean (µg)</th>
<th>% t</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite</td>
<td>Water</td>
<td>1.541033</td>
<td>1.931600</td>
<td>0.390567</td>
<td>25.3</td>
<td>5858.500 .000</td>
</tr>
<tr>
<td></td>
<td>Coke</td>
<td>1.564500</td>
<td>1.957633</td>
<td>0.393133</td>
<td>25.1</td>
<td>1179.400 .000</td>
</tr>
<tr>
<td>Fuji IX</td>
<td>Water</td>
<td>1.577533</td>
<td>1.904767</td>
<td>0.327234</td>
<td>20.7</td>
<td>981.700 .000</td>
</tr>
<tr>
<td></td>
<td>Coke</td>
<td>1.687167</td>
<td>2.015367</td>
<td>0.3282</td>
<td>19.5</td>
<td>93.454 .000</td>
</tr>
<tr>
<td></td>
<td>Fanta</td>
<td>1.5414</td>
<td>1.915567</td>
<td>0.374167</td>
<td>24.3</td>
<td>6874.510 .000</td>
</tr>
<tr>
<td>Amalgomer CR</td>
<td>Water</td>
<td>1.324733</td>
<td>1.685</td>
<td>0.360267</td>
<td>27.2</td>
<td>2997.600 .000</td>
</tr>
<tr>
<td></td>
<td>Coke</td>
<td>1.417600</td>
<td>1.798933</td>
<td>0.381333</td>
<td>26.9</td>
<td>3172.885 .000</td>
</tr>
<tr>
<td></td>
<td>Fanta</td>
<td>1.359733</td>
<td>1.756633</td>
<td>0.3969</td>
<td>29.2</td>
<td>6874.510 .000</td>
</tr>
</tbody>
</table>

Table 3. Cumulative weight gained by the restorative materials and the different media

<table>
<thead>
<tr>
<th>Materials</th>
<th>Weight gain in the three Media</th>
<th>Total weight gain caused by the media</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water</td>
<td>Coke</td>
</tr>
<tr>
<td>1 Composite</td>
<td>0.390567</td>
<td>25.3</td>
</tr>
<tr>
<td>2 Fuji IX</td>
<td>0.380167</td>
<td>24.7</td>
</tr>
<tr>
<td>3 Amalgomer CR</td>
<td>0.360267</td>
<td>27.2</td>
</tr>
<tr>
<td>Total weight gain</td>
<td>1.131001</td>
<td>33.9</td>
</tr>
</tbody>
</table>

Water absorption has been found to affect the mechanical properties of the materials exposed to it and cause damaging dimensional changes. Any absorption, which causes a dimensional change has potentially important clinical consequences. Furthermore, if the absorption also results in a significant generation of pressure it can be damaging to the material [15,16] and if the material is constrained within a cavity or is being used as a luting agent can also be damaging to the associated tooth structures and restorative materials [17,18]. Nevertheless, the precise effect of fluid absorption depends on many factors including not only the rate and amount of fluid absorbed but also on the mechanism of absorption [13].

The method used to study the weight change or water absorption in the materials is simple; for example by calculating the difference between the weights after immersion and before immersion of test materials. However, as opined by McCabe and Rusty (2004) the ease of measurement can hide a complexity of accompanying mechanism and a variety of consequences which depend upon the mechanism. Clearly, as found in this study the degree of absorption differ among the various test materials. We also agreed that small dimensional changes occurring as a result of water absorption can also be difficult to measure [13].

Although the method of specimen preparation and obtaining the gain in weight was similar to that of Khalil [14], it should be noted at the outset that comparisons with other studies are difficult to make due to differences highlighted by Burrow and Imokoshi et al. [19] in 1999. For example differences in specimen size; since different sizes of specimen will take different periods of time for water to completely infiltrate throughout a solid specimen. The smaller the specimen, the shorter the period for equilibration with water, and the materials which absorbed more water also took longer to stabilize.

Mohsen and Craig [20] opined that water sorption test also assumes that the weight gain in the samples represents the water gain, when in reality it is the difference between the gain in water and the dissolution of low molecular weight organics; thus, the true water sorption values would be somewhat higher than those reported. The constant handling of the specimens especially when transferring to and from the weighing machine was also said to have the tendency of causing minute wear of the surface, leading to a reduction of weight [21].
Toledano et al. [22] therefore suggested that studies determining the water sorption and solubility of resin-based materials are important mainly for their relative values but numerical comparisons are not always possible.

Findings show that all the materials absorbed water and consequently gained weight after 120 hours which probably revealed their tendency to absorb fluid from the environment. There are noticeable differences in the weight gain among the dental materials and the three media. This is not unexpected because sorption and solubility of tooth coloured restorative materials have been said to depend on various factors such as type of material, composition of matrix, filler particles, efficiency of polymerization as well as immersion media used [23,24].

In this study, it was observed that Composite had the least percentage weight gain only in Fanta and next to Fuji IX in water and Coke. Composite resins are so named because they are combination of two or more macromolecules mutually connected with a clearly recognizable coupling agent [25]. When they are combined; they produce a more superior property than that of the individual molecule. Initially, composite materials were primarily developed for fillings on anterior teeth but recent developments have seen improvement in the mechanical properties and because of these, they are now applicable as posterior restorative materials [26]. Mechanical properties of composites are well known to be influenced not only by their chemical composition but also by the environment to which they are exposed [27].

Water sorption affects the physical and mechanical properties of resin composite, such as dimensional change [28,29], decrease in surface hardness and wear resistance [30], filler leaching and change in color stability [16], reduction in elastic modulus [31], an increase in creep and a reduction in ultimate strength [32], fracture strength, fracture toughness, and flexural strength [33].

Hybrid composite resin was developed to combine different sizes of filler particles. The advantage of this combination is that the hybrid composite combines the advantage of the different particle sizes it contains [26,34]. This combination allows the highest level of filler loading (small particles lodging into the spaces of the larger sizes) which could be as high as 80-90% by weight or 65-77% by volume. Thus they have higher mechanical properties. Nowadays, hybrid resin composite is recommended for use in a wide range of clinical situations. It contains fine and microfine filler particles that occupy around 80wt% of the resin material [35].

Prime–Dent Microhybrid was used in this study. It is a visible light cure composite resin-based dental restorative material for anterior and posterior restorations. Since the filler particles of composite do not absorb water, there is still need for modifications of constituents even in microhybrid materials with improved mechanical properties to reduce their water absorption.

One of the most significant advances in the world of dental restorative materials has been the development of glass ionomer cement (GIC). It was first developed in England by Wilson and Kent in the year 1972 for use as a dental cement [36,37]. However, researchers observed its potentials to be useful for both anterior and posterior restorations; thus, the materials have been the focus of a great deal of researches in recent years with the goal of improving its mechanical properties. 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 [22, 38].

The development of Highly Viscous GIC resulted in materials with improved mechanical properties. The powder is chemically modified during manufacturing to decrease the calcium content and thus limit the production of calcium polyalkenoate chains which are highly water soluble. This allows faster maturation of the material but decreases the translucency. They obviously have higher compressive strength than the conventional glass ionomer cements which may be classified as low viscosity materials [37].

Fuji IX<sub>GP</sub> is an example of highly viscous material. The calcium in conventional GIC has been largely replaced with strontium which is a bioactive material. It is said to set extremely hard and is very wear resistant. In this study, it was observed that Fuji IX<sub>GP</sub> (GC, Japan) had the least weight gain in water and in Coke.
The material with the greatest percentage weight gain in the three media is Amalgomer CR Amalgomer CR (Advanced Healthcare LTD, UK) is a ceramic reinforced GIC. This is a relatively new Glass ionomer cements for the restoration of posterior teeth and so far one of the most recent advancement made on GIC as a posterior restorative material [8]. It was developed and released into the market in 2003. It incorporates ceramics (fine particles of zirconium) into the powder component which greatly increases its mechanical property [39, 40].

Among the three fluids used in this study, water was found to cause the most weight gain, next is Coke and Fanta in that order. In our opinion, this observation may probably be due to the traditional low pH and sugary constituents of Coke and Fanta which altered their absorption rate consequent upon the lower percentages than that of distilled water.

However, as concluded by Catani-Lorente et al. [41] these materials should not be concluded as not adequate for use in applications in direct contact with oral fluids because the test materials in oral cavities would not be affected to the same extent as in in vitro tests. In an oral environment, the constituents of saliva will certainly decrease the rate of water sorption and will hence delay its effects.

5. CONCLUSION

All the materials gained weight after 120 hours of immersion in distilled water, Coke and Fanta. The differences in weight before and after immersion were statistically significant. This revealed a tendency for all of them to absorb fluid from their environment. Fuji IX gained the least weight in water and Coke while Composite gained the least weight Fanta. Amalgomer gained the most weight in the three media. Water was found to cause the most weight gain while Fanta was the least. Although activities in the oral environment are quite different from in vitro conditions, oral health practitioners may need to be cautious in their application especially when optimum material's manipulation and application are lacking. Continuous improvement in the properties of these materials is warranted.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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