

# INFLUENCE OF PHOTOCURING AND STORAGE TIME ON THE VOLUMETRIC CHANGE OF RESIN MODIFIED GLASS IONOMER CEMENTS

## ABSTRACT

**AIM:** This study evaluated the effect of photoactivation and storage on the hygroscopic expansion of resin modified glass ionomers (Vitremer-3M/ESPE, Fuji II LC-GC Int., Vitro Fil LC-DFL). **MATERIAL AND METHODS:** The RMGIC were manipulated according to the manufacturer's instructions, inserted into a mold and kept in a darkness box for 15 minutes. Then, the samples were distributed into four groups (n=5): light-cured for 20s, light-cured for 40s, light-cured for 60s and not light-cured (control group). Each sample was storage in distilled water at 37°C. The measurements of volumetric changes were made in three different times of storage: 24 hours, 7 days and 30 days. Volumetric changes were determined using Archimedes principle. Means and standard deviations values were analyzed by three-way analysis of variance and Tukey's test to compare significance between the groups ( $\alpha=0,05$ ). **RESULTS:** All materials underwent volumetric expansion after 30 days. Vitremer showed the less expansion when no light-cured. The time of light-cure did not influence the volumetric change, except for Fuji II LC, that showed great expansion when activated for 60s. Vitro Fil LC showed some degree of shrinkage after 7 days. **CONCLUSION:** This study concluded that photocuring can influence the volumetric change of resin modified glass ionomer cement.

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## KEYWORDS

Glass ionomer cements. Dental materials. Operative dentistry.

## INTRODUCTION

Resin modified glass ionomer cement (RMGIC) appeared in the late 1980s, with the insertion of resinous monomers in the conventional glass ionomer cement liquid<sup>1</sup>. Polymerization of this resinous portion was activated by specific light energy, in which the matrix formed mixed with the acid-based reaction products of the conventional ionomeric cements<sup>2-4</sup>.

This alteration produced an improvement in the mechanical properties of the material, in addition to prolonging the working time and improving its translucence<sup>5</sup>. However, it was found that RMGIC presented a high rate of water absorption when compared with other restorative materials<sup>3,6-9</sup>.

This occurs for two main reasons: (1) the presence of the hydrophilic resinous monomer HEMA, and (2) the retardation of the acid-based reaction, typical of the ionomeric portion, due to replacing part of the organic acid solution with the resinous portion<sup>9-11</sup>. Thus, the hydrogel phase, critical as regards water absorption, is significantly increased<sup>9</sup>.

It is known that water absorption by the restorative material is directly related to its increase in volume<sup>6</sup>, therefore the use of modified glass ionomer cement could be restricted in some clinical situations due to its significant increase in volume in an aqueous medium<sup>12-14</sup>.

Some manufacturers inform that in their products, polymerization activation of the resinous portion of modified glass ionomer cement may occur in two ways: by means of an activator molecule (chemical activation), or after activation of the initiator molecule by light energy for this purpose (photoactivation). Other manufacturers suggest that the resinous portion of the cement is polymerized only by light activation.

The aim of this study was to relate the light polymerization time, or its absence, to the volumetric change in the resin modified glass ionomer cement, with the intention of providing greater safety in the clinical use of the material.

## MATERIAL AND METHODS

In the present research, three commercial brands of resin modified glass ionomer cement were used, as described in the table below.

### MAKING THE SPECIMENS:

Sixty (60) specimens were made, being 20 of each material, which were distributed into the following groups (n=5). Group 1: specimens light polymerized for 20 s. Group 2: specimens light polymerized for 40 s. Group 3: specimens light polymerized for 60 s. Group 4: Control Group, without polymerization.

Each test specimen measured 5mm +/- 0.1 in diameter by 2mm +/- 0.1 thickness. A

polytetrafluorethylene (PTFE) matrix was used to make the specimens.

Table 1. Commercial brands of materials used.

Brand Name	Manufacturer	Composition of powder	Composition of liquid
Vitremer(V)	3M/ESPE, St. Paul MN, USA	Fluoroaluminosilicate glass	HEMA, water and polyalkenoic acid copolymer of carboxylic acid
Fuji II LC (FII)	GC Corp. Tokyo, Japan	Aluminum silicate glass	Polyacrylic acid, HEMA, TMHMD, own ingredients
VitroFil LC (VF)	DFL, RJ, Brazil	Stroncio-aluminum silicate, load, activators	HEMA, aqueous solution of polyacrylic acids, benzoyl peroxide and camphoroquinone

The powder and liquid of each material were manipulated with the powder/liquid ratio, by weight, established by the manufacturers. Next, the mixture was inserted in a disposable syringe tip (Centrix/DFL, RJ, Brazil) in the PTFE matrix, placed on a microscope glass slide. The slide was covered with a polyester strip to prevent the cement from coming into contact with the glass. After the cement was inserted, another polyester strip and glass slide were placed over the matrix. A 0.5 Kg weight was applied on the set, allowing the material to overflow out of the matrix cavity. The set was then put into a hermetically closed cardboard box, which prevented light from entering inside it. Each sample remained in the box for 15 minutes.

After being removed from the box, the specimens of Groups 1, 2 and 3 were light activated by halogen light (Optilux 501 / Demetron-Kerr), with a controlled power

density of 500 mW/cm<sup>2</sup> for 20, 40 and 60 seconds, respectively.

After the specimens were removed from the matrix, a No.12 scalpel blade was used to remove the excess material. Next, the first sequence of specimen weighing was performed, using an analytical balance with a density specification appliance.

Firstly, the specimen was weighed in the conventional manner, in the specific area of the analytical balance for obtaining the real initial weight in air (Wd). Afterwards, the specimen was weighed to determine the apparent mass in water (Wa). Next, each specimen in the group was inserted in a black plastic flask with 10 ml of distilled water. The flasks were closed and placed in an autoclave with an internal temperature of 37°C.

After insertion and compression inside the PTFE matrix, the specimens of group 4 (control group) were kept inside the cardboard

box, protected from the light for 15 minutes, without any type of light polymerization. Afterwards, the sets were removed from the box and the matrix, and were submitted to the same finishing and weighing processes as the previous groups, until being inserted into the storage flask.

#### WEIGHING THE SPECIMENS AT SPECIFIC TIMES:

All the specimens were weighed 24 hours, 07 days and 30 days after storage. Each test specimen was removed from the flask and carefully dried with absorbent paper for 20 seconds. After that, each test specimen was put into the region of the balance where dry weighing was done, to gauge the weight in air at time  $t$  ( $M_{d.t}$ ) and then each specimen was weighed in distilled water ( $M_{a.t}$ ), at a temperature of  $23 \pm 1^\circ\text{C}$ .

#### THEORETICAL DEVELOPMENT OF THE ARCHIMEDES PRINCIPLE:

Firstly, the masses of the specimens must be established by weighing. In the first stage, the masses are obtained before storage in an aqueous medium, in which one obtains: (1)  $M_d$  – dry mass (weighed in a dry environment); (2)  $M_a$  – apparent mass (weighed in the fluid).

In the second stage, one obtains the masses of the specimens after storage for a certain time, in which one obtains: (1)  $M_{d.t}$  –

dry mass after the storage period  $t$  (weighed in a dry environment); (2)  $M_{a.t}$  – apparent mass after the storage period  $t$  (weighed in the fluid).

Requiring obtainment of the volumetric alteration ( $\Delta V$ ), one has the value of  $V_1$ , which is the volume of the altered material, after storage and  $V_0$ , which is the original volume of the material.

One knows that:  $\Delta V (\%) = (\Delta V / V_0) \times 100$ , or  $\Delta V (\%) = [(V_1 - V_0) / V_0] \times 100$ , or  $\Delta V (\%) = [(V_1 / V_0) - 1] \times 100$ .

The Archimedes principle says that the volume of the displaced liquid is the same as that of the volume of the material inserted in the fluid. This is equal to the increase in mass of the material, divided by the density of the fluid ( $d$ )<sup>17</sup>, or that is to say:  $V = (\Delta M) / d = (M_s - M_a) / d$ .

By applying this equation to the alteration in volume, one obtains:  $V_1 - V_0 = (M_{s.t} - M_{a.t}) / (M_s - M_a)$ .

Substituting the equations, one obtains the formula that is used:  $\Delta V (\%) = \{[(M_{s.t} - M_{a.t}) / (M_s - M_a)] - 1\} \times 100$ .

The means of the results, in percentages, of the volumetric alteration were submitted to Analysis of Variance for three criteria, and afterwards, to the Tukey test to verify the significance among the groups ( $\alpha=0.05$ ).

## RESULTS

Similar lower case in each column indicate no statistically significant between groups and similar upper case in each line indicate no statistically significant difference between storage times.

The results demonstrated that for the Vitremer brand, the absence of light polymerization had an influence on volumetric variation.

Table 2. Means of the results of volumetric alterations (%) and respective standard deviations.

	24H	7D	30D
V sf	0.91(0.62) <sup>aB</sup>	0.30(0.73) <sup>aA</sup>	0.42(0.51) <sup>aAB</sup>
V 20s	5.35(0.84) <sup>cdA</sup>	5.44(0.69) <sup>cdA</sup>	5.72(0.69) <sup>cdeA</sup>
V 40s	4.25(0.52) <sup>cdA</sup>	4.87(0.61) <sup>bcB</sup>	4.76(0.66) <sup>bcB</sup>
V 60s	4.01(1.27) <sup>bcA</sup>	5.17(0.77) <sup>bcB</sup>	5.02(0.77) <sup>bcB</sup>
FII sf	5.24(1.01) <sup>cdA</sup>	5.78(0.78) <sup>cdA</sup>	5.19(1.01) <sup>bcdA</sup>
FII 20s	5.81(1.11) <sup>cdA</sup>	6.22(0.91) <sup>cdA</sup>	6.10(1.22) <sup>cd.eA</sup>
FII 40s	5.44(1.22) <sup>cdA</sup>	6.08(1.09) <sup>cdB</sup>	6.14(1.26) <sup>cd.eB</sup>
FII 60s	5.83(0.26) <sup>dA</sup>	6.69(0.76) <sup>dAB</sup>	6.72(0.89) <sup>deB</sup>
VF sf	2.07(0.61) <sup>abA</sup>	3.42(0.34) <sup>bB</sup>	3.36(0.34) <sup>bB</sup>
VF 20s	3.59(0.89) <sup>bcA</sup>	4.48(0.38) <sup>bcB</sup>	3.46(0.34) <sup>bcA</sup>
VF 40s	3.66(0.29) <sup>bcA</sup>	4.69(0.19) <sup>bcB</sup>	3.83(0.41) <sup>bcA</sup>
VF 60s	4.55(0.89) <sup>cdA</sup>	4.91(0.54) <sup>bcdA</sup>	4.44(0.67) <sup>bcdA</sup>

Fuji II LC was the material that expanded most hygroscopically. The absence of light at the initial moment of the setting reaction did not appear to have an influence on this process. The storage time had an influence on the alteration in volume of the materials, however, there was a trend towards diminishing volume of Vitro Fil LC brand specimens. The variation of light polymerization time between 20 s and 60 s showed no statistical significance in hygroscopic expansion after 30 days.

## DISCUSSION

The Archimedes principle has been known and used for a long time to assess dimensional alterations in material, but it is

not routinely used in researching biomaterials<sup>6</sup>. This equation can easily be used, not only in water, but also in non-aqueous fluids. A notable disadvantage in using the Archimedes principle to assess dimensional alteration is that the loss of mass in the storage period is seen as a false contraction of the material<sup>15-17</sup>.

After inserting the material in the PTFE matrix, there was a waiting period of 15 minutes in a dark environment before the 1st weighing sequence, because after pilot tests it was found that it was the minimum time necessary for obtaining a consistency that made it possible to work with the unpolymerized specimens, and thus be able to standardize all the groups.

Water absorption is a controlled diffusion process that occurs in the organic matrixes of resins<sup>9,18,19</sup>. The HEMA is present in hydrogel form in the polymerized matrixes, which generates high water absorption<sup>7,20,22,23</sup>. Hydrophilic polymers form the hydrogel phase, which absorbs a great deal of water and undergoes great hygroscopic expansion<sup>19,22</sup>. Hydrogel formation becomes greater due to the slower reaction of the ionomeric part of the material, with less water available for the acid-based reaction<sup>10,15,24</sup>. It is possible that the hydrophilic resinous matrix, containing polyalkenoate salts, creates an osmotic gradient that attracts water to the material<sup>11</sup>. The mixed linear polymeric chains of HEMA attract water molecules and keep them bonded through hydrogen bridges<sup>11</sup>, and the structural and topological characteristics are fundamental for determining how much each polymer will be affected by the aqueous medium<sup>24</sup>. The studies of Soles and Yee<sup>25</sup> (2000) concluded that the extent and rate of water absorption in the polymeric chains are predominantly controlled by two factors: the polarity of the resin, dictated by the concentration of hydrogen bridge forming niches with water, and the topology of the chain, which is related with the cohesive energy density of the polymeric network.

It was verified that FII was the material that expanded most after 30 days of storage in distilled water. This result was compatible

with some previously conducted researches<sup>5,7,27</sup>. The lowest quantity of crossed links of this material, when compared with Vitremer, is pointed out as one of the main causes of the greater hygroscopic expansion, as there is less space between the chains for water penetration<sup>27</sup>.

Fuji II LC demonstrated no significant alteration when it was not light polymerized, and it seemed that some form of polymerization occurred in the dark environment. Although the manufacturer informs that Fuji II LC has no mechanism for chemical initiation of the HEMA polymerization reaction, this information is questioned by some authors<sup>28-30</sup>.

Vitremer presented the least hygroscopic expansion when it was not light polymerized. As the Archimedes equation does not take into account the solubility of the material, as the specimens were stored in water the entire time, one can affirm that the loss of weight of specimens, which led to diminished volume of the material, is indeed the result of its solubilization. This points towards a deficiency in the chemical initiation process of HEMA in Vitremer<sup>28</sup>. However, Kakaboura, Eliades and Palaghias<sup>29</sup> (1996) observed the high acid-based reaction rate of Vitremer not exposed to light polymerization, they suggested that there could be inefficient polymerization initiation or the slow rate of chemically initiated polymerization allows

efficient acid neutralization rates. However, other authors related that the triple setting reaction, which is announced by Vitremer, is an indication of a good polymerization process in the absence of light<sup>11,29</sup>.

Few researches are found as regards Vitro Fil LC, and none related to its water absorption process, however, the triple setting process, as the manufacturer informs, seems to exist. Further research about the polymerization process are necessary in order to find out more about this brand and its clinical application.

The storage time influenced the dimensional alteration of CIVMRs. As the setting reaction takes place almost completely in the first 24 hours, in this period when the hydrogel phase occurs, there is greater water absorption. Hygroscopic expansion of dental materials is a process that can occur for years<sup>14</sup>. Therefore, it was noted that it was difficult to establish a time for this process to enter into equilibrium, since some degree of leaching of the material occurs simultaneously, as was noted with greater significance in Vitro Fil LC.

It is difficult to avoid CIVMR coming into contact with humidity, since dentin is very humid, and the deeper the cavity is, the greater the presence of fluids<sup>11</sup>, therefore the greater the formation of poly-HEMA hydrogel. Therefore, knowledge of the hygroscopic expansion process is fundamental for planning

the restorative treatment with CIVMR, so that the clinical stages are well performed and there is good treatment longevity.

## CONCLUSION

From the study, it could be concluded that: Vitremer was influenced by the absence of light polymerization, the variation in polymerization time does not alter the hygroscopic expansion of CIVMRs, Fuji II LC had the greatest hygroscopic expansion among the tested materials and the storage time influences the volume of the CIVMR.

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