

8-31-2020

Changes in the Surface Roughness of Glass Ionomer Cement and Zirconomer after Immersion in Carbonated Beverages

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Recommended Citation

Chair Effendi, M., Nugraeni, Y., Hartami, E., & Nurul Ummah, A. Changes in the Surface Roughness of Glass Ionomer Cement and Zirconomer after Immersion in Carbonated Beverages. *J Dent Indones.* 2020;27(2): 85-90

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Cover Page Footnote

Acknowledgement We thank all the staff of Skills Laboratory-Faculty of Dental Medicine Universitas Brawijaya, Biochemistry Laboratory-Faculty of Medicine Universitas Brawijaya, Industrial Metrology Laboratory-Faculty of Mechanical Engineering Universitas Brawijaya, and all the individuals who have helped in the completion of this research.

ORIGINAL ARTICLE

Changes in the Surface Roughness of Glass Ionomer Cement and Zirconomer after Immersion in Carbonated Beverages

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ABSTRACT

Nano glass ionomer cement (GIC) with nano zirconia as a raw material called zirconium is a newly developed type of restoration/tooth filling material that is used in dentistry. **Objective:** To examine the effect of carbonated beverages on the surface roughness of Zirconomer and GIC filling materials and determine if there was any difference between them. **Methods:** This is a true-experimental laboratory research study with a pre-posttest group design. The research samples consisted of 32 samples, 16 GIC samples and 16 Zirconomer samples, further divided into four time-sensitive groups: day 1, day 3, day 5, and day 7. The samples were immersed in artificial saliva and carbonated beverages for 24 hours. Surface roughness was measured using a surface roughness tester. **Results:** The average surface roughness from day 1 to day 7 of the GIC material immersed in carbonated beverages was 4.17 μm , which is higher than the average surface roughness of Zirconomer (3.091 μm), and the difference was significantly different ($p < 0.01$). **Conclusion:** Zirconomer was found to be more resistant to carbonated beverages than GIC. There was a positive correlation between the length of immersion time in the carbonated beverages and the surface roughness of GIC and Zirconomer.

Key words: carbonated beverages, glass ionomer cement, zirconomer

How to cite this article: Effendi MC, Nugraeni Y, Hartami E, Ummah AN. Changes in the surface roughness of glass ionomer cement and zirconomer after immersion in carbonated beverages. *J Dent Indones.* 2020; 27(2):85-90

INTRODUCTION

Dental caries is a prevalent problem in Indonesia; 73.4% of Indonesian children, ranging in age from 10 to 14, suffer from cavities.¹ According to the World Health Organization (WHO) data in 2016, 60–90% of school-age children and almost all adults, worldwide, have dental caries.² Dental caries require medical care to restore the function of the tooth by filling it with restoration materials that are now shifting to more adhesive and aesthetic non-metallic materials, such as composite resin and glass ionomer cement (GIC).^{3,4} GIC is often used as a restoration material for deciduous teeth.⁵ The latest development is nano GIC with a nano zirconia-based material called zirconium. Zirconomer is also known to be strong, condensable, and durable like amalgam, and it can also release fluoride, similar to

GIC. Nano GIC was developed by adding nanoclusters from silica and zirconia to both pastes.⁶⁻⁸ Nano particles are 1–100 nm sized materials in one dimension, such as groups of atoms, grains, fibers, and films with thicknesses < 100 nm.⁹

In the present study, GIC type II was used as a restorative material. Other types of ionomer cements are an ionomer with metal-fused-to-glass-particles and Resin Modified Glass Ionomer Cement. GIC is presented in the form of a solution of polymeric acid and glass powder. Approximately 50% concentration of polyacrylic acid solution was used in GIC.^{10,11} GIC compositions include silica (SiO_2), alumina (Al_2O_3), aluminum fluoride (AlF_3), calcium fluoride (CaF_2), sodium aluminum hexafluoride (NaAlF_6), and aluminum phosphate (AlPO_4). Sodium (Na_+), calcium

(Ca₂₊) or strontium (Sr₂₊) ions render GIC susceptible to acids. Strontium has the effect of increasing radiopaque properties, thus, giving GIC an aesthetic appearance.¹² Carbonated beverages were first manufactured in 1830 with an additional mixture of sweeteners and fruit flavor variations, and they were developed using a variety of packages.¹³ Carbonated beverages consist of 90% carbonmonoxide gas water, 10% sugar, artificial or original coloring, concentrates, acidity regulators, and caffeine,¹⁴ which causes increased roughness on the restorative surface and increased solubility of the GIC restorative material.^{15,16} The average consumption of carbonated beverages per person is 2.4 liters per year, and each year that continues to increase by 4%.¹⁷ Research has shown that acids in carbonated beverages with a low pH of ± 2.5 can cause chemical reactions that dissolve the ions of the spilled material, thus changing the surface roughness of a tooth's restorative material.¹⁸ Therefore, it is imperative to investigate the effect of carbonated beverages on the difference in surface roughness changes between GIC and Zirconomer filling materials.

METHODS

This is a true-experimental laboratory research study with a pre-posttest group design. The research samples consisted of 32 samples: 16 GIC samples and 16 Zirconomer samples. The samples were divided into four groups based on immersion time, with four samples in each group: Group 1 (day 1), Group 2 (day 3), Group 3 (day 5), and Group 4 (day 7).

Manufacturing the GIC and Zirconomer samples

The GIC and Zirconomer samples were made using the same method. Measuring the GIC and Zirconomer powder and liquid was done according to the manufacturer's instructions using different mixing pads. Manipulation was performed using a GIC spatula and by dividing the powder into two parts. The first part of the powder was stirred with liquid until it was homogeneous; the second part of the powder was stirred using a folding motion until a thick putty-like consistency was reached and the Zirconomer was visibly shiny. After the GIC and Zirconomer were manipulated, the results were put into two plastic rings as molds, one each for GIC and Zirconomer, which were previously made and placed on a glass lab (A) using a plastic filling instrument until the mold was full. Celluloid strips were placed on top of the printed material to obtain a smooth and perfect GIC and Zirconomer surface. A new glass lab (B) was then placed on the celluloid strip, and pressed until the surface of the printed product was flat and parallel to the bottom of glass lab (A) (see Figure 1). It took up to 3–5 minutes for the GIC and Zirconomer to harden, after which the samples were varnished using a cotton pellet. The samples were stored in a closed plastic

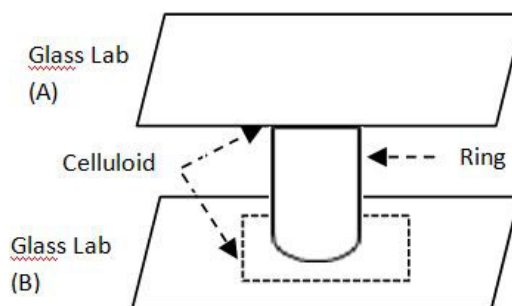


Figure 1. The vertical sample molding process for GIC and Zirconomer.

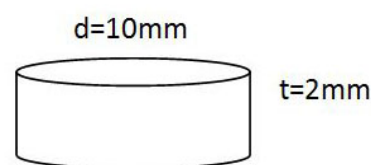


Figure 2. The shape and dimensions of the research sample.

container; it took 24 hours to achieve the required hard setting.

The samples that had reached the hard setting (24 hours) were shaped cylindrically with a diameter of 10 mm and a thickness of 2 mm (Figure 2).

Immersion of the samples in artificial saliva

After 24 hours in a closed plastic container, all the samples were put into different plastic containers labeled 1 to 32. Then, 5 ml of artificial saliva was poured into each plastic container, and the container was tightly closed. All the samples were then stored in an incubator at 37°C. After 24 hours, all the samples were removed and drained dry on gauze. The samples were returned to the original plastic containers, labeled 1 to 32. They were then sent to the Industrial Metrology Laboratory to measure the surface roughness of the treatment samples (pre-test) using a surface roughness tester. The roughness average (RA) value of each sample was then recorded. After all the samples were tested, all were given a treatment, i.e., they were immersed in carbonated beverages with a different immersion duration for each group. Each group consisted of four samples with a total of eight groups in different containers assigned a sequential number.

Sample immersion and treatment procedure

All the samples were grouped into eight groups, each group consisting of four samples. After immersing the samples in artificial saliva for 24 hours, they were placed into containers that were labeled 1 to 32 and a

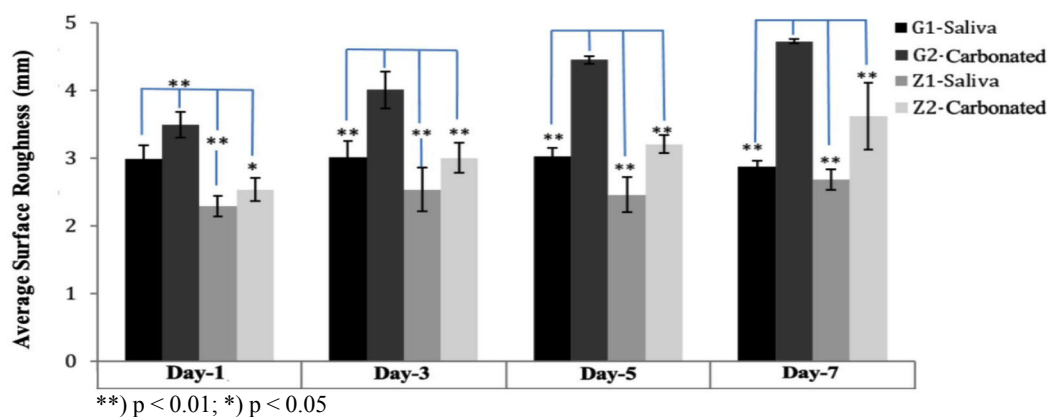


Figure 3. Mean difference in the surface roughness for GIC and Zirconomer from day 1 to day 7; GIC immersed in artificial saliva (G1); GIC immersed in carbonated beverages (G2); Zirconomer immersed in artificial saliva (Z1); Zirconomer immersed in carbonated beverages (Z2).

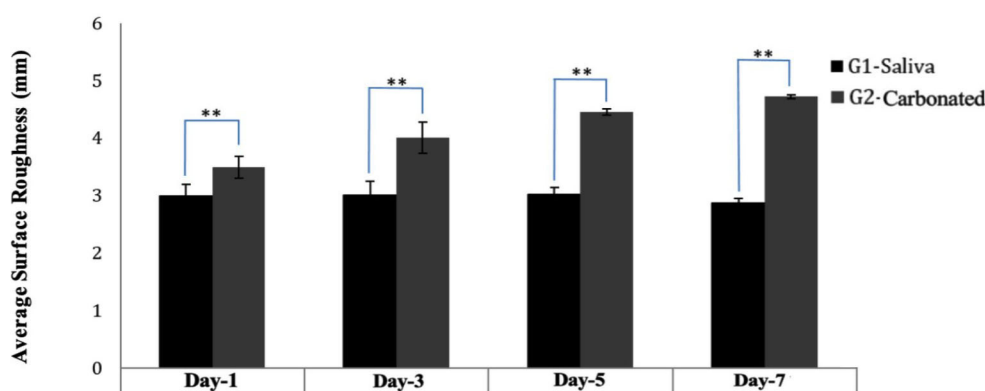


Figure 4. Mean differences in the surface roughness of GIC immersed in artificial saliva (G1) with GIC immersed in carbonated beverages (G2) from day 1 to day 7. **) $p < 0.01$; *) $p < 0.05$

surface roughness test was conducted. The acidity of the carbonated beverages was measured, then 5 ml of the carbonated beverages was poured into each container (numbered 1 to 32). All the sample containers were stored in an incubator; the temperature was adjusted and the carbonated beverages were replaced every 24 hours. The samples that had reached the duration of immersion were divided into groups as follows: day 1, day 3, day 5, and day 7 (GIC immersed in saliva = G1; GIC immersed in carbonated beverages = G2; Zirconomers immersed in saliva = Z1; Zirconomer immersed in carbonated beverages = Z2). The samples were then removed from the container and drained dry on gauze. Next, the samples were inserted into plastic clips that had been numbered according to the sample number.

Surface roughness test

Each sample was placed on the glass lab and its surface roughness was measured sequentially according to the sample number using the Surface Roughness Tester (Mitutoyo-210, Japan) to obtain an RA value for the R-curve. The RA values were recorded on the monitor screen connected to the surface roughness tester

Data analysis

To determine the differences in surface roughness in each group (four groups—GIC with Zirconomer data), one-way ANOVA was performed; Tukey's test was used to determine the differences between the four groups and the paired t-test was used to evaluate the differences in surface roughness between GIC and Zirconomer (within) after the samples were immersed in artificial saliva and carbonated beverages. The differences in surface roughness between the GIC and the Zirconomer materials were identified using an independent t-test test; Pearson's correlation test was utilized to determine the relationship between immersion duration and the GIC and Zirconomer surface roughness.

RESULTS

The results of the one-way ANOVA and Tukey's tests showed that, on day 1, the average surface roughness was coarser for G2 than G1, and the difference was statistically significant ($p < 0.01$). Moreover, the surface roughness was coarser for G2 than for Z1 and Z2, and

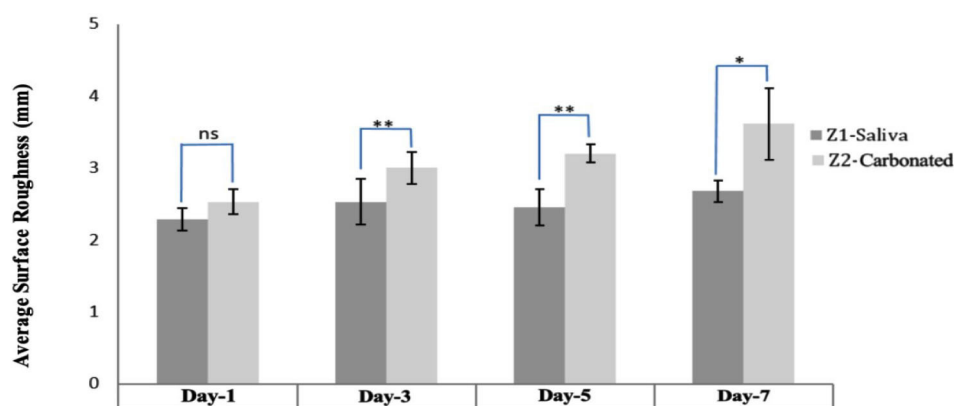


Figure 5. Mean difference in the surface roughness of Zirconomer immersed in artificial saliva (Z1) and Zirconomer immersed in carbonated beverages (Z2) from day 1 to day 7. ** $p < 0.01$; * $p < 0.05$; ns) not significant.

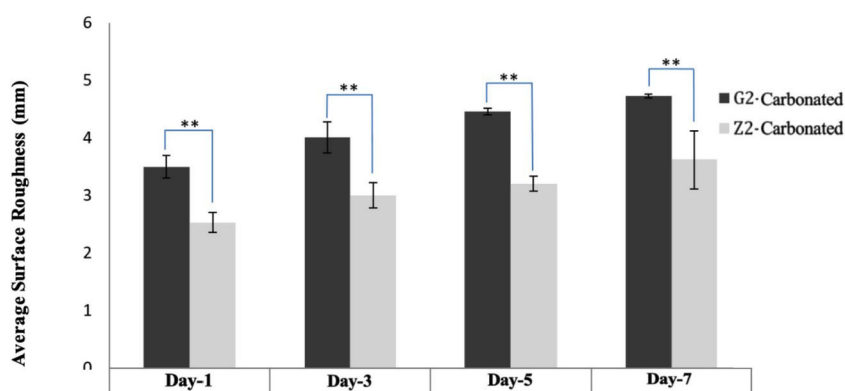


Figure 6. Mean differences in the surface roughness of GIC immersed in carbonated beverages (G2) and Zirconomer immersed in carbonated beverages (Z2) from day 1 to day 7. ** $p < 0.01$; * $p < 0.05$

it was significantly different ($p < 0.01$); additionally, Z2 had a rougher surface than Z1, and the difference was statistically significant ($p < 0.05$).

On day 3 and day 5, the samples that were immersed in carbonated beverages demonstrated a significant difference in surface roughness than the samples immersed in artificial saliva; the average surface roughness of G2 was $4.710 \mu\text{m}$ in comparison to Z1 ($2.491 \mu\text{m}$) and Z2 ($3.091 \mu\text{m}$). Likewise, Z2 had a rougher surface in comparison to Z1 ($p < 0.01$). On day 7, only G1 and Z1 had no significant difference in surface roughness (see Figure 3).

A paired t-test (pre and posttest) was administered to ascertain the difference in surface roughness between G1 and G2. There was a significant difference ($p < 0.01$) from day 1 to day 7. The average surface roughness was lower for G1 ($2.971 \mu\text{m}$) than G2 ($4.710 \mu\text{m}$). The average surface roughness of G2 increased from day 1 to day 7 (Figure 4).

A paired t-test (pre and posttest) was done to determine the difference in the surface roughness Z1 and Z2. On day 1, there was no significant difference ($p > 0.05$) between the surface roughness of Z1 and Z2. On day 3, the surface roughness was higher for Z2 ($3.005 \mu\text{m}$) than Z1 ($2.535 \mu\text{m}$). On day 5, the surface roughness was higher for Z2 ($3.618 \mu\text{m}$) than Z1 ($2.457 \mu\text{m}$), and the difference was statistically significant ($p < 0.01$). On day 7, the surface roughness was higher for Z2 ($3.618 \mu\text{m}$) than Z1 ($2.682 \mu\text{m}$), and the difference was significant ($p < 0.05$), with the average surface roughness increasing in comparison to the previous day (Figure 5).

An independent t-test was performed to determine the differences in the average surface roughness of GIC and Zirconomer immersed in carbonated beverages. The statistical test results revealed that the average surface roughness was higher for G2 ($4.170 \mu\text{m}$) than Z2 ($3.091 \mu\text{m}$), and the difference was statistically significant ($p < 0.01$). The surface roughness of these

Table 1. Correlation of GIC and Zirconomer materials immersed in carbonated beverages with surface roughness

Restorative Materials	Surface Roughness			
	Day 1	Day 3	Day 5	Day 7
GIC (r)	0.998 (very strong)	0.982 (very strong)	0.223 (weak)	0.541 (very strong)
Zirconomer (r)	0.990 (very strong)	0.168 (very weak)	0.942 (very strong)	0.318 (weak)

materials increased after being immersed in carbonated beverages from day 1 to day 7, but the increase was higher in the GIC material (Figure 6).

As seen in Table 1, the results of the Pearson's correlation test on day 1 show a very strong and significant positive correlation between the surface roughness of the material ($p < 0.01$; $r = 0.998$) and immersion in carbonated beverages ($p < 0.01$; $r = .990$). On day 3, the correlation between surface roughness and the GIC immersed in carbonated beverages was very strong and significantly positive ($p < 0.04$; $r = 0.982$). In contrast, no significant relationship was found between the surface roughness and the Zirconomer immersed in carbonated beverages ($p > 0.05$); the correlation coefficient was very low ($r = 168$). On day 5, the correlation between GIC immersed in carbonated beverages and surface roughness demonstrated a low and insignificant correlation ($p > 0.05$; $r = 0.223$).

The correlation between the surface roughness of Zirconomer immersed in carbonated beverages was significant ($p < 0.05$), with a very strong correlation coefficient ($r = 0.942$). On day 7, GIC and Zirconomer immersed in carbonated beverages had an insignificant correlation ($p > 0.05$) with the surface roughness of the material. The GIC correlation coefficient was very strong ($r = 0.541$) and the Zirconomer correlation coefficient was low ($r = 0.318$).

DISCUSSION

Carbonated beverages are one of the causes of changes in the surface roughness of tooth enamel and the surface of restorative materials. Increased surface roughness can facilitate bacterial colonization in the form of plaque attached to the restorative material. This can cause secondary caries and periodontal inflammation.¹⁵

The surface roughness test results using the Surface Roughness Tester show that the average surface roughness of the samples immersed in saliva was higher for GIC (2.971 μm) than Zirconomer (2.491 μm) from day 1 to day 7 (Figure 3). The average surface roughness of the samples immersed in a

carbonated beverage was higher for GIC (4.170 μm) than Zirconomer (3.091 μm) from day 1 to day 7 (Figure 6). This is because Zirconomer exhibits good resistance to abrasion and erosion.⁶ The abrasion occurs due to mechanical factors and the erosion is caused by chemical factors, including the pH of saliva and carbonated beverages. The statistical test results show that the duration of immersion of carbonated beverages influences the difference in the surface roughness of GIC and Zirconomer. The duration of immersion of carbonated beverages significantly increased the surface roughness of GIC from day 1 to day 7 in comparison to Zirconomer (Figure 6). This clearly demonstrates that Zirconomer is more resistant to acids than GIC because the average surface roughness value is lower for Zirconomer than it is for GIC after being immersed in carbonated beverages.

The results of this study are in agreement with the findings reported in other studies that show that the duration of immersion of the samples in carbonated beverages affects the surface roughness of GIC because the beverage is acidic with a low pH of ± 2.5 , which causes erosion of GIC¹⁸ and the acidic content of carbonated beverages has a corrosive nature that can cause solubility in GIC ions.¹⁹ Hydrogen ions from carbonated beverages will bind cations to GIC, and then the cations are released from GIC and cause pores to form.¹⁷ The surface hardness of GIC was relatively low at 48 KHN; the surface hardness of the composite resin was around 50–60 KHN; thus, its ability to withstand abrasion is lower.²⁰ Calculus and debris can stick to restorations that have a surface roughness caused by carbonated beverages, and it can cause continuous exposure. This also increases the surface roughness of the filling.²¹

Zirconomer's base materials are composed of nano particles, making them more resistant to erosion in comparison to GIC.²² Therefore, after immersing the Zirconomer samples in carbonated beverages, the average surface roughness increase was not very significant from day 1 to day 7 in comparison to GIC. As seen in Figure 5, on day 1 the immersion of the Zirconomer samples in carbonated beverages and in artificial saliva did not yield significant differences. This indicates that the duration of contact of Zirconomer with carbonated beverages is determined by the length of the immersion, which is also the case for GIC.

Pearson's correlation results (Table 1) reveal that the correlation coefficient was positive, signifying that when the immersion in carbonated beverages is longer, the surface roughness of the material increases, as seen on day 1 for GIC and Zirconomer, day 3 for GIC, and day 5 for Zirconomer; moreover, the correlation was significant. Insignificant correlations and low and very low correlation coefficients may be due to incorrect mixing of the ratio of the powder and liquid ingredients or too little sample data.

CONCLUSION

From day 1 to day 7, the average surface roughness of the samples immersed in a carbonated beverage was higher for the GIC (4.17 μm) than for Zirconomer (3.091 μm). The duration of immersion of carbonated beverages significantly increases the surface roughness of GIC from day 1 to day 7 in comparison to Zirconomer; this proves that Zirconomer is more resistant to acids than GIC. The correlation results show a positive correlation between the immersion time in carbonated beverages and the increased surface roughness of GIC and Zirconomer.

ACKNOWLEDGEMENT

We thank the staff at the Skills Laboratory-Faculty of Dental Medicine Universitas Brawijaya, Biochemistry Laboratory-Faculty of Medicine Universitas Brawijaya, Industrial Metrology Laboratory-Faculty of Mechanical Engineering Universitas Brawijaya, and all the individuals who helped in the completion of this research.

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(Received June 19, 2020; Accepted August 3, 2020)