Effects of CPP-ACP paste application on surface roughness of resin-modified glass ionomer cement (RM-GIC) immersed in Coca-Cola®

To cite this article: A Al-Akmaliyah et al 2018 J. Phys.: Conf. Ser. 1073 032030

View the article online for updates and enhancements.
Effects of CPP-ACP paste application on surface roughness of resin-modified glass ionomer cement (RM-GIC) immersed in Coca-Cola®

A Al-Akmaliyah¹, E Herdastri¹* and M Damiyanti¹

¹Department of Dental Material, Faculty of Dentistry, Universitas Indonesia, Jakarta 10430, Indonesia

*E-mail: ellyza_herdas@yahoo.com

Abstract. This study describes the effects of casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) paste on the surface roughness of resin-modified glass ionomer cement (RM-GIC) immersed in Coca-Cola® for 30 min. RM-GIC specimens were evaluated under different conditions: immersion in aquabidest (control, group 1); immersion in Coca-Cola® (group 2); immersion in Coca-Cola® immediately after smearing with CPP-ACP paste (group 3); and immersion in Coca-Cola® 30 min after smearing with CPP-ACP paste (group 4). There was a significant increase in the surface roughness of the specimens in group 2, an obvious but insignificant decrease in the surface roughness of the specimens in group 3, and a significant decrease in the surface roughness of the specimens in group 4. The results showed that the treatment of RM-GIC specimens with CPP-ACP paste with or without a 30-min delay results in no significant change in surface roughness from immersion in Coca-Cola®.

1. Introduction

Carbonated beverages are highly popular among the people of Indonesia and drinks from various brand names are often available at home, in fast food and regular restaurants, cafes, mini markets, and stores throughout the country. Carbonated drink consumption in Indonesia was 1.8% each year from 2004–2010, with a consumption rate of 13 serving sizes with the size of 236 ml for each person per year [1]. Coca-Cola® is one of the most widely-consumed carbonated beverages in Indonesia. Coca-Cola® contains water, sugar, carbonic acid, artificial coloring, phosphoric acid, flavoring, and caffeine [2]. It also has a low pH (2.5) compared with other carbonated beverages [3]. The low pH of Coca-Cola® has been reported to erode tooth surfaces and restorative materials, increasing surface saturation [4].

Resin-modified glass ionomer cement (RM-GIC) is a restorative material widely used in dentistry for class III and V restorations, as well as for bases, liners, core buildups, and adhesives [5]. The development of RM-GICs began in 1976 with the aim of improving the physical properties and reducing the water sensitivity of conventional GIC [6,7]. The composition of RM-GIC resembles that of the conventional GIC, with the only difference being the addition of hydroxyethyl methacrylate (HEMA) resin and a photoinitiator. The setting reaction that occurs in RM-GIC consists of an acid-base reaction and resin polymerization with light activation [6]. The advantages of RM-GIC over conventional GIC are increased attachment strength, meaning that the attachment of RM-GIC to the
tooth structure is better than that of GIC, as well as greater flexural strength, a longer fluoride-release, and ease of use [8].

Two of the main objectives of tooth restoration are caries healing and secondary caries prevention. Caries is a hard tissue disease of the tooth caused by the dissolution of enamel by an acid produced by bacteria in the mouth from the metabolism of food carbohydrates [9]. Therefore, surface characteristics such as the surface roughness of the restorative material are important. Surface roughness refers to undesirable irregularity on the surface, usually due to friction, excessive use, scratching, fatigue, and chemicals [10]. Increased surface roughness leads to greater plaque accumulation and bacteria, increasing the risk of caries and periodontal inflammation [11]. The surface of some restorative materials including RM-GIC has been reported to show increased roughness due to erosion or corrosive wear through the process of degradation and dissolution of the material [12].

The casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) paste was recently introduced for use in tooth restoration. Casein phosphopeptide, or CPP, is a casein that is phosphorylated or bound to a phosphate group. When stabilized by CPP, calcium phosphate turns into amorphous calcium phosphate (ACP). Researchers have been investigating the anticariogenic effects of milk proteins contained in CPP-ACP as well as its role as a remineralization agent since 1990 [13]. Several previous studies have shown that CPP-ACP can increase the micro-hardness of enamel, reduce the erosion caused by carbonated beverages, and increase the bond-strength microtensile and compressive strength of RM-GIC. Additionally, CPP-ACP can significantly increase the release of calcium, phosphate, and fluoride at neutral or acidic pH [14,15]. However, there have been few studies on the effects of CPP-ACP on the surface roughness of RM-GIC when exposed to acidic food or drink. Considering the importance of the surface roughness of restorative materials in maintaining their restorative function, this study was conducted to determine the effects of CPP-ACP paste application on the surface roughness of RM-GIC after immersion in a carbonated beverage, Coca-Cola®.

2. Methods

2.1. RM-GIC specimens
RM-GIC from Fuji II LC was manipulated under the manufacturer instruction (w/p = 2:1). The entire mass of the RM-GIC was placed in a cylindrical stainless steel mold previously smeared with silicone oil as a separation medium and with a diameter of 6 mm and a height of 3 mm. The top surface of the material was coated with Mylar strips and glass preparations to provide a smooth surface [16]. The 500-g mass was placed on top of the preparatory glass for 2 min then cured with visible light for 20 s. Twenty four specimens were created and separated into four groups, each group consisting of six specimens. Each group was placed in a plastic pot containing aquabidest and stored in an incubator at 37 °C for 24 h to ensure a 24-h maturation period after manipulation [6,16].

2.2. Initial surface roughness measurement
The specimens were removed from the incubator after 24 h. The initial surface roughness was measured for each specimen using the Surface Roughness Tester Mitutoyo SJ 301. Measurements were performed by placing the stylus attached to the device on the surface of the specimen and the results were viewed on the monitor screen. Measurements were obtained three times from different parts of each specimen.

2.3. Treatment
Aquabidest, Coca-Cola® at 9 °C, and CPP-ACP GC Tooth Mousse paste were prepared. For group 1 (control group), 50 ml of aquabidest was poured into a plastic pot containing six specimens, which were immersed for 30 min. The initial pH of the Coca-Cola® used was measured with a pH indicator, which showed a range of pH 2–3. For group 2, 50 ml of Coca-Cola® was added to a plastic pot containing six specimens, which were immersed for 30 min. A thin layer of CPP-ACP GC Tooth
Mousse paste (0.0083 g) was smeared on the surface of each specimen in group 3. Afterward, 50 ml of Coca-Cola® was added to a pot with the specimens and the specimens were allowed to sit for 30 min. The pH of the Coca-Cola® during immersion ranged from pH 3–4. CPP-ACP GC Tooth Mousse paste was smeared in a thin layer (0.0083 g) on the surface of each specimen in group 4. The specimens were stored for 30 min in accordance with fabric instructions. Afterward, 50 ml of Coca-Cola® was added to a pot containing the specimens and the specimens were immersed for 30 min. The pH of Coca-Cola® during immersion ranged from pH 4-5. All immersed specimens were dried using a water spray.

2.4. Measurement of surface roughness after treatment
The surface roughness of each specimen was measured again with the Surface Roughness Tester Mitutoyo SJ 301.

2.5. Repeat Treatment
The treatments were repeated in each group for 3 x 30 min to replicate teeth conditions after 18 days of Coca-Cola® consumption. The immersion time in Coca-Cola® was determined with the assumptions as follows. Drinking a bottle of Coca-Cola® takes approximately 5 min. Assuming Coca-Cola® is consumed once a day, immersion of RM-GIC for 30 min in Coca-Cola® would have the same effect as Coca-Cola® consumption for six days.

In this study, the specimens were immersed three times for 30 min. The total length of immersion was 30 min x 3 = 90 min, which is equivalent to Coca-Cola® consumption for 18 days (90 min/5 min = 18 days).

2.6. Data Analysis
Data analysis was performed using one way analysis of variance (ANOVA) and repeated ANOVA.

3. Results
Table 1 shows the changes in the surface roughness of the RM-GIC for each group: immersion in aquabidest (group 1); immersion in Coca-Cola® (group 2); application of CPP-ACP paste and direct immersion in Coca-Cola® (group 3); and smearing with CPP-ACP paste followed by immersion in Coca-Cola® after 30 min (group 4).

The surface roughness of the specimens immersed in aquabidest (control, group 1) and Coca-Cola® (group 2) increased significantly (p < 0.05), whereas the values for the group smeared with CPP-ACP paste and immersed in Coca-Cola® after a 30-min delay (group 4) decreased significantly (p < 0.05).

The mean differences in surface roughness between the RM-GIC groups after the first 30 min of immersion can be seen in Table 2. The table shows that there was a statistically significant difference between groups 1 and 4, between groups 2 and 3, and between groups 2 and 4.

| Group | Surface Roughness / Ra ± SD (µm) |
|-------|---------------------------------|
|       | Initial | First 30 minutes | Second 30 minutes | Third 30 minutes |
| 1 - Aquabidest | 0.520 ± 0.151 | 0.622 ± 0.169 | 0.672 ± 0.144 | 0.723 ± 0.142 |
| 2 - Coca-Cola® | 0.520 ± 0.151 | 0.775 ± 0.249 | 0.943 ± 0.258 | 1.178 ± 0.340 |
| 3 - CPP-ACP+Coca-Cola® | 0.520 ± 0.151 | 0.418 ± 0.121 | 0.372 ± 0.125 | 0.347 ± 0.137 |
| 4 - CPP-ACP (30 minutes) + Coca-Cola® | 0.520 ± 0.151 | 0.318 ± 0.091 | 0.232 ± 0.061 | 0.297 ± 0.143 |
### Table 2. Mean Differences in Surface Roughness in the First 30 Min.

|                          | 1 - Aquabidest ∆Ra (µm) | 2 - Coca-Cola® ∆Ra (µm) | 3 - CPP-ACP+Coca Cola® ∆Ra (µm) | 4 - CPP-ACP (30 minutes) + Coca Cola® ∆Ra (µm) |
|--------------------------|-------------------------|--------------------------|---------------------------------|---------------------------------------------|
| 1 - Aquabidest ∆Ra (µm)  | -                       | 0.153                    | 0.203                           | 0.303*                                      |
| 2 - Coca-Cola® ∆Ra (µm)  | 0.153                   | -                        | 0.357*                          | 0.457*                                      |
| 3 - CPP-ACP + Coca-Cola® ∆Ra (µm) | 0.203 | 0.357* | - | 0.100 |
| 4 - CPP-ACP (30 minutes) + Coca Cola® ∆Ra (µm) | 0.303* | 0.457* | 0.100 | - |

(*) Statistically significant difference. Results from one way ANOVA ($p < 0.05$)

The mean differences in surface roughness between the RM-GIC groups after the second 30 min of immersion can be seen in Table 3. The table shows that there was a statistically significant difference in surface roughness between group 1 and the other three groups as well as between group 2 and the other three groups.
Table 4. Mean Differences in Surface Roughness in the Third 30 Min.

|                  | 1 - Aquabidest ΔRa (µm) | 2 - Coca-Cola® ΔRa (µm) | 3 - CPP-ACP+Coca Cola® ΔRa (µm) | 4 - CPP-ACP (30 minutes) + Coca Cola® ΔRa (µm) |
|------------------|------------------------|-------------------------|---------------------------------|-----------------------------------------------|
| 1 - Aquabidest   |                        | 0.455*                  | 0.377*                          | 0.427*                                        |
| ΔRa (µm)        |                        |                        |                                 |                                               |
| 2 - Coca-Cola®  | 0.455*                 | -                      | 0.832*                          | 0.882*                                        |
| ΔRa (µm)        |                        |                        |                                 |                                               |
| 3 - CPP-ACP +   | 0.377*                 | 0.832*                 | -                               | 0.050                                        |
| Coca-Cola®      |                        |                        |                                 |                                               |
| ΔRa (µm)        |                        |                        |                                 |                                               |
| 4 - CPP-ACP (30 minutes) + Coca Cola® | 0.427* | 0.881* | 0.050 | - |
| ΔRa (µm)        |                        |                        |                                 |                                               |

(*) Statistically significant difference. Results from one way ANOVA (p < 0.05)

The mean differences in surface roughness after the third 30 min of immersion can be seen in Table 4. The table shows that there was a statistically significant difference between group 1 and the other three groups as well as between group 2 and the other three groups. The surface roughness values for groups 3 and 4 were not significantly different after the first, second, and third immersions.

4. Discussion

The results of this study show that RM-GIC immersion in aquabidest and Coca-Cola results in an increase in surface roughness. However, CPP-ACP application prior to immersion in Coca-Cola results in a decrease in surface roughness, although this decrease does not change significantly between immersions.

One of the factors that increase the surface roughness of RM-GIC is the size of the filler particles. Gladys et al. reported that filler particles with larger sizes have greater surface area and are more reactive to the polymer, thus reducing the formation of air bubbles [16]. Oya et al. (2012) also demonstrated that RM-GIC with a particle size of 5.9 µm has a finer consistency than does conventional GIC with a particle size of 10.0 µm. However, in terms of wear resistance the surface of RM-GIC with smaller particle sizes becomes rougher than that of conventional GIC after exposure to abrasive and erosive materials [18].

The initial surface roughness for the RM-GIC specimens in group 1 (control) was 0.548 µm, which increased to 0.723 µm (increase of 0.175 µm) after three immersions lasting 30 min each (90 min total). In group 2, the surface roughness value for the RM-GIC specimens was initially 0.495 µm and increased to 1.178 µm (increase of 0.683 µm) after three immersions in Coca-Cola® with a pH of 2-3. This was the highest surface roughness value obtained in this study.

The increase in the surface roughness of RM-GIC after immersion in aquabidest was due to the process of dissolution and degradation. Dissolution is mainly influenced by the diffusion of ions through water. Previous study suggested that greater and faster diffusion occurs through the resin matrix contained in the RM-GIC than through the polymeric acid matrix of the conventional GIC acid-base reaction, because water absorption in the RM-GIC is greater [16]. This is a result of the hydrophilic HEMA in RM-GIC. Water absorption through the resin matrix can also cause degradation
due to the hydrolysis process on the filler and matrix bonds. The effects of this hydrolysis include reduced molecular weight, weakening of filler and matrix bonds, and decrease of the physical and mechanical properties of RM-GIC, which increase the surface roughness of the material [19].

The increase in the roughness of RM-GIC after immersion in Coca-Cola is due to the composition of Coca-Cola. The phosphoric acid and citric acid in Coca-Cola can remove or break down calcium ions on the matrix surface. Citric acid has the ability to alter the calcium ions located in the cement matrix, dissolving the ions in Coca-Cola®. This can lead to irregularities on the surface of the material [16]. In addition, Fukazawa et al. (1990) stated that the high acidity of Coca-Cola affects cement dissolution due to the diffusion of the cement matrix ions. This process is dependent on the concentration of H+ ions. The more acidic a solution, the more H+ ions will be released and the higher the potential for cement dissolution and surface degradation [20]. This statement is supported by the results of this study, in which the surface roughness of RM-GIC specimens immersed in Coca-Cola was greater than that of specimens immersed in aquabidest [21].

In group 3, the initial RM-GIC surface roughness was 0.520 μm, which decreased to 0.347 μm (decrease of 0.173 μm) after three immersions in Coca-Cola®, with a pH of 3–4. The increase in pH was due to the release of calcium (Ca²⁺) and phosphate (PO₄³⁻) ions from CPP-ACP in the acidic environment. The calcium and phosphate ions would attract H+, forming neutral ions [13]. More neutral ions and fewer H⁺ would cause the pH to increase, preventing dissolution and degradation of the material. In addition, CPP-ACP can deposit calcium and phosphate ions on porous surfaces. The calcium and phosphate ions that fill the porous surface will reduce the roughness of the surface [22]. The specimens in group 3 showed significant changes in surface roughness, likely because the surface of RM-GIC was already exposed to Coca-Cola® before adequate amounts of calcium and phosphate were deposited on the surface.

In group 4, the initial RM-GIC surface roughness value was 0.517 μm, which decreased to 0.297 μm (decrease of 0.220 μm) after three immersions in Coca-Cola® with a final pH of 4–5. In this group, the pH increase was significant, increasing from pH 2-3 to pH 4–5. The decrease in surface roughness in this group is attributed to the higher pH environment, which would have caused the formation of a nano complex on CPP-ACP that bound and locked the appropriate amounts of calcium phosphate. This would lead to mineral deposition on the surface of the glass ionomer cement before degradation from exposure to the Coca-Cola carbonic acid drink, making the surface of RM-GIC smoother [22].

The results of this study demonstrate that Coca-Cola® can significantly increase the surface roughness of RM-GIC compared with aquabidest starting from the second 30 min of immersion. In contrast, smearing RM-GIC with CPP-ACP paste followed by direct immersion in Coca-Cola® can significantly decrease the surface roughness of RM-GIC starting from the second 30 min of immersion. Polishing RM-GIC for 30 min with CPP-ACP paste followed by immersion in Coca-Cola® can significantly reduce the surface roughness starting from the first 30 min of immersion. There was no significant difference between the group treated with CPP-ACP paste followed immediately by immersion in Coca-Cola®, and the group smeared with CPP-ACP paste and immersed in Coca-Cola® after a 30-min delay. The lack of significant differences in these two groups is attributed to an equal decrease in the surface roughness due to the deposition of calcium and phosphate on the porous surfaces.

5. Conclusion
The results of this study show that the surface roughness of RM-GIC increases significantly after immersion in Coca-Cola® but decreases significantly after RM-GIC is smeared with CPP-ACP paste for 30 min before immersion. The surface roughness of the RM-GIC immersed in Coca-Cola® immediately after smearing with CPP-ACP paste also decreased, although not significantly. The difference in the mean surface roughness value for both groups of RM-GIC specimens treated with CPP-ACP paste indicated that the duration of CPP-ACP application has no effect on the surface roughness of RM-GIC.
References

[1] Hubungan antara Advertisement Media Televisi dengan Brand Awareness Produk Coca Cola® Company. [cited 20 Sep 2012]; Available from: http://www.repository.upi.edu/operator/upload/s_pet_022712_chapter4.pdf.

[2] Marie Anne. Ingredients in Coke 2010 [cited 20 Sep 2012]; Available from: http://www.chemistry.about.com/b/2010/04/26/ingredients-in-coke.htm.

[3] Jain P, Nihill P, Sobkowski J and Agustin M Z 2007 Commercial Soft Drinks: pH and in vitro Dissolution of Enamel Gen. Dent. 55 151–4

[4] Wan Bakar W Z, Abdullah A and Hussien A 2012 Erosion effect of acidic drinks on two types of glass ionomer cement Malays. Dent. J. [cited 20 Sept 2012]; Available from: http://www.mdj.org.my/index.php?option=com_content&view=article&id=137&catid=53&Itemid=133

[5] Anusavice K J 2004 Philip: Buku Ajar Ilmu Bahan Kedokteran Gigi. 10th ed. (Jakarta: Buku Kedokteran EGC) p 57–9, 449–60

[6] Mount G J and Hume W R 2005 Preservation and Restoration of Tooth Structure. 2nd ed. (Knowledge Books and Software) p 21–34, 83–109, 111–8, 163–97, 204

[7] Pedrini D, Candido M S M and Rodrigues Jr A L 2003 Analysis of surface roughness of glass ionomer cements and comomer J. Oral Rehabil. 30 714–9

[8] Berzins D W, Abey S, Costache M C, Wilkie C A and Roberts H W resin modified glass ionomer setting reaction competition J. Dent. Res. 89 82–6

[9] Decker R T and Loveren C V 2003 Sugars and dental caries Am. J.Clin. Nutr. 78 881S–92S.

[10] Bagheri R, Burrow M F and Tyas M J 2007 Surface characteristics of aesthetic restorative materials—an SEM study J. Oral Rehabil. 34 68–76

[11] Preto R 2006 Surface roughness of glass ionomer cement indicated for Atraumatic Restorative Treatment (ART) Braz. Dent. J. 17 106–9

[12] Reynolds E C, Cai F, Shen P and Walker G D 2003 Retention in plaque and remineralization of enamel lesions by various forms of calcium in mouthrinse or sugar-free chewing gum J. Dent. Res. 89 206–11

[13] Reynolds E C 1998 Anticariogenic complexes of amorphous calcium phosphate stabilized by casein phosphopeptide: a review Spec. Care Dent. 18 8–16

[14] Mazzauoci S A, Burrow M F, Tyas M J, Dashper S G, Eakins D, Reynolds E C 2003 Incorporation of casein phosphopeptide amorphous calcium phosphate into a glass ionomer cement J. Dent. Res. 82 914–8

[15] O’Brien W J 2008 Dental Materials and Their Selection. 4th ed. (Illinois: Quintessence Publishing Co, Inc.) p. 146–55, 156–64

[16] Gao F, Matsuya S, Ohta M and Zhang J 1997 Erosion process of light-cured and conventional glass ionomer cements in citrate buffer solution. Dent. Mat. J. 16 170–9

[17] Gladys S, van Meerbeek B, Braem M, Lambrechts P and Vanherle G 1997 Comparative psycomechanical characterization of new hybrid restorative materials with conventional glass ionomer and resin composite restorative materials J. Dent. Res. 76 883–94.

[18] Oya B, Arisu Deniz H, Yukilgan I, Arslan S and Gullu A 2012 Evaluation of surface roughness and hardness of different glass ionomer cements. Eur. J. Dent. 6 79–86

[19] Lamis A, Anas F M and Abdulla M W The effect of pepsi cola beverage on surface roughness of two composite resins (in vitro study). Malays. Dent. J. 7 9–14

[20] Fukuzawa M, Matsuya S and Yamane M 1990 The mechanisme for erosion for glass ionomer cement in acidic buffer solution J. Dent. Res. 69 1175–9

[21] Matsuya S, Matsuya Y, Yamamoto Y and Yamane M 1984 Erosion process of a glass ionomer cement in acidic buffer solution J. Dent. Res. 66 1170–4

[22] Prabhakar A R, Mahantesh T, Vishwas T D and Kabade A 2009 Effect of surface treatment with remineralizing on the color stability and roughness of esthetic restorative materials Revista de Clinica e Pesquisa Odontologica J. 5 19–27