



## The Effect of Carbonated Drinks with Different Low pH Levels on Surface Roughness of Nano-filled Composite Resin

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### ARTICLE INFO

#### Article history:

Received 22 April 2024

Received in revised form 01 June 2024

Accepted 06 June 2024

Available online 09 June 2024

#### Keywords:

Carbonated Beverages

Dental Restoration Wear

Immersion

### ABSTRACT

**Background and aim:** Nano-filled composite resins are popular due to their small filler size, which results in a smooth restoration surface, a vital physical property. The consumption of carbonated drinks is increasing. Continuous exposure in a low pH environment causes composite resin's surface roughness. A rough surface accumulates dental plaque, which causes various dental complications.

**Material and methods:** This research used 27 Filtek Z350XT nano-filled composite samples prepared using disc-shaped 8mm diameter and 2mm thickness. Samples were divided into three groups: a control group of pH 7.0 distilled water, carbonated drink A of pH 2.4, and carbonated drink B of pH 2.9, immersed in 5mL vials for two hours per day for 15 days. The surface roughness of samples was measured before and after immersion on day 15 using a surface roughness tester. Changes in surface roughness were analyzed using One Way ANOVA and Post Hoc Test.

**Results:** Surface roughness of samples immersed in the control group, carbonated drink A of pH 2.4 and carbonated drink B of pH 2.9 respectively to be  $0.1333 \pm 0.07331 \mu\text{m}$ ;  $0.8011 \pm 0.07897 \mu\text{m}$ ;  $0.5311 \pm 0.08695 \mu\text{m}$ . One-way ANOVA showed a significant difference in the surface roughness of nano-filled composite resin samples.

**Conclusions:** Based on the results, it can be concluded that after 15 days of immersion in carbonated drinks with low pH levels, the surface roughness of nano-filled composite resin significantly increased.

### 1. Introduction

Composite resin is one of the most popular tooth restoration materials. Composite resins have been used in dentistry for more than 50 years to restore caries and enamel abrasion due to their high aesthetic value compared to other restorative materials.<sup>[1]</sup> A composite resin comprises three major components: resin matrix, inorganic filler, and coupling agent.<sup>[2]</sup> The resin matrix provides strength, plasticity, and curing characteristics. Inorganic filler improves compressive strength, elastic modulus, hardness, and wear resistance. The coupling agent chemically links the filler and resin matrix to achieve bonding. Initiating systems such as polymerization promoting systems promote the polymerization reaction. Others, like colorants, stabilizer systems, catalysts, and more, act as an auxiliary enhancement effect.<sup>[3]</sup> Many types of composite resin differ by various classification systems according to their different compositions and characteristics. The most used classification system is based on the distribution and average filler particle size. According to Lutz and Philips's classification system 1983, composites can be divided into macrofilled, microfilled, hybrids, modern hybrids, and nanofilled composites.<sup>[3]</sup> Nanofiller composite resin is highly used in dentistry as a

restoration material.<sup>[4]</sup> Nanofilled composite resin has 10-100nm dimensions, providing great aesthetic and strength and low polymerization shrinkage due to a decreased resin matrix and increased filler loading.<sup>[3]</sup> Advances in nanotechnology produce composite resin, which has nanoparticles of 25nm and agglomerate nanoparticles of 75nm.<sup>[5]</sup> The nanofilled composite resin contains a minimal filler, about 5-20nm, consisting of zirconia-silica. The filler is in the form of nanomers and nanocluster particles. The combination of this particle and the small filler size makes nano-filled composite resin collect and produce denser mass quickly, which results in increased physical properties. The small filler size also results in an easier and smoother effect when polished, resulting in its popularity as a restorative material.<sup>[6]</sup> The consumption of carbonated drinks over the past several decades has increased dramatically, especially among children and adolescents.<sup>[7]</sup> Every year, the consumption of carbonated drinks increases among Indonesian citizens.<sup>[8]</sup> Carbonated drinks have a low pH level ranging from 2.4 to 4.07. Carbon dioxide dissolved in carbonated drinks increases acidity and decreases the pH of saliva.<sup>[9]</sup> Among others, continuous exposure in a low pH environment causes surface roughness of composite resin.<sup>[1]</sup> Low-pH drinks have acid with

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<https://doi.org/10.30485/IJSRDMS.2024.458844.1584>



high amounts of Hydrogen ions. These acids are called carbonic acid. The release of these hydrogen ions breaks the resin matrix bonding with the filler particles, resulting in loss of cohesion; the breaking of polymer chain bonds causes matrix degradation of composite resin. The degradation of the matrix causes the breakdown of the methacrylate group in Bis-GMA, which produces residual monomers. These residual monomers on the surface of composite resin cause roughness.<sup>[1]</sup> A smooth restoration surface has been one of the significant objectives in dental practice. A rough restoration surface

affects the aesthetic and oral health of soft tissues and the marginal integrity of the restorative interface. Increased surface roughness can cause discoloration, staining, loss of gloss, and accumulation of dental plaque, which could lead to caries development and periodontal inflammation over time.<sup>[10]</sup> The research aims to study the effect of carbonated drinks with different low pH levels on the surface roughness of nanofilled composite resin.

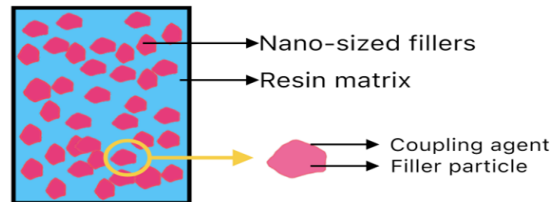


Fig. 1. Structure of Nanofilled Composite Resin.

Table 1. Comparison of prior studies and our study.

Author	Type of Composite Resin	Treatment Groups	Surface Roughness Measurement	Result	Difference
Phanestu <i>et al.</i> , 2018	A polished 8mm diameter and 2mm thickness of disk-shaped nano-filled composite resin (Filtek Z350XT, 3M ESPE, USA)	Immersion of composite resin in black tea for 1 hour, 2 hours, 3 hours, and 4 hours.	Surface roughness was measured using a profilometer (MarSurf M300, Germany)	An increase in surface roughness of the composite resin was observed.	This study determined that immersion time in black tea affects the surface roughness of nanofilled composite resin.
Isabel <i>et al.</i> , 2016	An unpolished 10mm x 2mm Cylindrical Nanofilled Composite Resin (Filtek Z350, 3M ESPE, USA)	Immersion of composite in Coca-Cola, Coffee, Black tea, and Red Wine for one hour per day, observed for three months, six months, nine months, and 12 months.	Surface roughness was measured using a roughness meter (Surftest SJ-301 Mitutoyo, Japan)	Coca-Cola, Coffee, and Black tea increased the surface roughness of resin composites.	This study observed a longer duration of exposure to various low-pH drinks (monthly).
Liliany and Violetta, 2020	Unpolished 10mm in diameter and 2mm in height cylindrical nano-filled composite resin (Filtek Z250 XT, 3M ESPE, USA)	Composite resin was divided into two groups: preheated to 39°C (preheated using Ena Heat, Micerium S.p.A., Avegno GE, Italy) and non-preheated. Composite resin was immersed into an undisclosed soft drink for 2 hours daily for 12 and 15 days.	Surface roughness was measured using an optical profilometer (Taylor Hobson, Surtronic S-100 Series, S128)	Immersion in soft drinks increases the surface roughness of composite resin; no difference was observed between the preheated and non-preheated composites.	This study observed the effect of low-pH soft drinks in increasing the surface roughness of preheated and non-preheated composite resin.

## 2. Material and methods

Ethical Clearance was obtained from the Ethical Committee of the Faculty of Dentistry, Universitas Gadjah Mada (number: 004/KKEP/FKG-UGM/EC/2022). Two different solutions of carbonated drinks, carbonated drink A (Coca-Cola; Produced by: PT. Coca-Cola Bottling Indonesia, Bekasi-17520 Indonesia) and carbonated drink B (Fanta Orange; Produced by: PT. Coca-Cola Bottling Indonesia, Bekasi-17520 Indonesia) along with distilled water (Water for Injection; Produced by: PT. Ikapharmindo Putramas, Pharmaceutical Laboratories, Jakarta-Indonesia) as control negative were used. Surface roughness of resin samples made from Filtek Z350XT (A3.5 Body Shade; Produced by: 3M dental products St.Paul, MN 55144-1000 USA) with filler size 0.1-5.0 microns was measured on a Surface roughness tester (Starrett SR300, Taylor Hobson, Berwyn, PA, USA). The carbonated drinks used in the research were poured into 50mL beakers, respectively, and the pH was measured using a digital pH meter. The pH of carbonated drink A was 2.4, the pH of carbonated drink B was 2.9, and the pH of distilled water was 7.0. (Fig. 2)

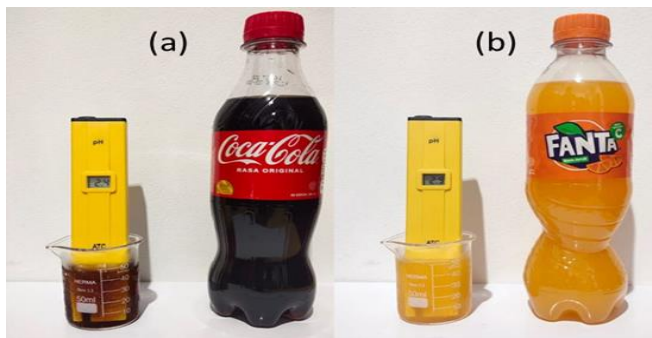


Fig. 2. pH measurement of carbonated drinks A and B.

The research samples were prepared by filling the metal mold with Filtek Z350XT nanofilled composite resin. The samples were made in the shape of a disc with a diameter of 8mm and a thickness of 2mm.<sup>[11]</sup> The materials were condensed into the mold. The mold was covered with cellophane strips at the top and bottom, and a glass plate was placed on top. The samples were cured using a light curing unit for 20 seconds with a gap of 1mm from the sample surface in an upright position. Samples were taken out after setting. Samples were polished using a fine-grade sandpaper of 180-220 grit. Between each polishing step, the specimens were thoroughly rinsed with water to remove debris and dried using absorbent paper. The number of samples used in this research was nine for each group. There were three groups. Hence, 27 samples were prepared. (Fig. 3)

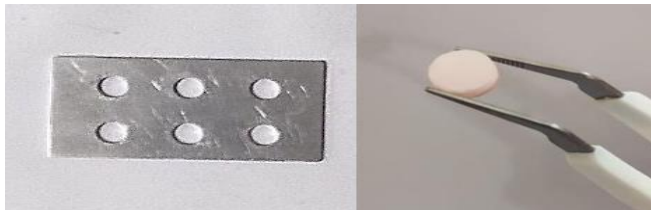


Fig. 3. Composite resin mold and a sample of the nanohybrid composite resin.

Samples were rinsed with distilled water and then immersed in 5mL vials of distilled water for 24 hours.<sup>[11]</sup> The samples were immersed for two hours daily for 15 days in an immersion solution. Subject samples were immersed in individual vials containing 5mL of immersion solution. This simulated the consumption of carbonated drinks for 4 minutes per day for a month (4 minutes 30 days = 120 minutes = 2 hours). Fifteen days of total immersion period simulates 15 months of carbonated drink consumption in real life. After immersing in the respective solution, the samples of the experimental groups were stored in distilled water at room temperature. The samples removed from the solutions were cleansed using distilled water to remove any remnants from the surface.<sup>[12]</sup> All vials were sealed to prevent immersion solutions from evaporating, and immersion solutions were changed daily.<sup>[11]</sup> The surface roughness was measured using a surface roughness tester (Starrett SR300, Taylor Hobson, Berwyn, PA, USA). The surface roughness result was obtained from the motion signal of a diamond-shaped stylus moving along a straight line across the sample for as far as 4mm. The surface roughness of the sample was measured at three different points, and it was expressed as average roughness (Ra) in  $\mu\text{m}$ .<sup>[13]</sup> The procedure was repeated for all 27 samples. The surface roughness was measured before and after immersion on day 15.<sup>[12]</sup> Samples are cleaned and dried using absorbent paper before surface roughness measurement.<sup>[14]</sup>

## 3. Results

The data obtained from the surface roughness tester were quantitative on a ratio scale. The data were then analyzed using a parametric test, One-Way ANOVA, with a confidence level of 95%. Mean values and standard deviations of the final surface roughness value and initial surface roughness value in nano-filled composite resin samples are presented in Table 2.

Table 2. Mean increase on surface roughness of nano-filled composite resin after immersion in low pH level carbonated drinks.

Groups	Mean $\pm$ standard deviation ( $\mu\text{m}$ )
Negative control (distilled water) of pH 7.0	0.1333 $\pm$ 0.07331
Carbonated drink A of pH 2.4	0.8011 $\pm$ 0.07897
Carbonated drink B of pH 2.9	0.5311 $\pm$ 0.08695

Shapiro-Wilk normality test showed normal data distribution in all three groups with significance level  $p > 0.05$ , respectively. Levene's homogeneity test showed a normal distribution with equal variances  $p = 0.824$ , with a significant level of  $p > 0.05$ . Homogeneity of variance and normality tests were the precondition for further parametric test One-way ANOVA. The results of One-Way ANOVA are shown in Table 3.

Table 3. One-Way ANOVA.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.031	2	1.016	158.915	0.001
Within Groups	0.153	24	0.006	----	----
Total	2.185	26	----	----	----

\*df = degree of freedom, F = obtained statistic, Sig. = p-value.

One-way ANOVA showed a significant effect on the surface roughness of the nanofilled composite resin samples with a value of  $p=0.001$ , indicating that different low pH levels of carbonated drinks significantly affect the surface roughness of nanofilled composite resin. Further analysis of the Post

Hoc Test is shown in Table 4. Post Hoc Test, the least significant difference showed a mean significant difference between each group with a value of  $p=0.01$ .

Table 4. Post Hoc Tests are the least significantly different.

	Control Negative (Distilled Dater)	Carbonated Drink A pH 2.4	Carbonated Drink B of pH 2.9
Control Negative (Distilled Water)	---	0.668*	0.398*
Carbonated Drink A of pH 2.4	---	---	0.270*
Carbonated Drink B of pH 2.9	---	---	---

\*= The mean difference is significant at the 0.05 level

#### 4. Discussion

The consumption of carbonated drinks has increased dramatically over the past several decades. Carbonated drinks supply energy due to their high sugar content but lack nutritional benefits, vitamins, and minerals. Carbonated drinks are also high in acidity.<sup>[7]</sup> The acidity of carbonated drinks causes a decrease in salivary pH, causing saliva covering the tooth to become unsaturated with calcium phosphate. These cause a decrease in the concentration of hydroxyapatite crystals that results in the demineralization of enamel and hypersensitivity of dentin.<sup>[6]</sup> The study's results showed an influence of carbonated drinks with low pH levels on the surface roughness of nanofiller-type composite resin. This is evident from the results showing an increase of  $0.8011\mu\text{m}$  in surface roughness value of samples immersed in carbonated drink A of pH 2.4 and an increase of  $0.5311\mu\text{m}$  in surface roughness value of samples immersed in carbonated drink B of pH 2.9. At the same time, only an increase of  $0.1333\mu\text{m}$  in the surface roughness value of samples immersed in a control negative group of distilled water was observed. The nano-filled composite resin contains a very small filler particle in the form of nanomers and nanocluster particles, which have denser masses and increased physical properties such as surface smoothness. The smooth surface of resin avoids plaque and biofilm formation, thus decreasing the risk of caries and periodontal inflammation. A rough surface causes a reduction of brightness, discoloration, and shortening of the age of restoration. A smooth surface is one of the physical properties of restorative materials that could potentially influence their success.<sup>[15]</sup> The consumption of carbonated drinks has increased dramatically over the past several decades. Carbonated drinks supply energy due to their high sugar content but lack nutritional benefits, vitamins, and minerals. Carbonated drinks are also high in acidity.<sup>[7]</sup> Carbonated drinks produce a pH ranging from 2.4 to 4.07. Carbon dioxide

dissolved in carbonated drinks increases acidity and decreases the pH of saliva.<sup>[9]</sup> Among others, continuous exposure in a low pH environment causes surface roughness of composite resin. Carbonated drinks contain carbonic acid, which releases hydrogen ions.<sup>[3]</sup> These acids act as oxidizing agents and catalysts in hydrolysis, which breaks the resin matrix bonding with the filler, resulting in loss of surface cohesion of the filling material. Breaking the bond results in the degradation of composite resin by breaking the polymer chain into an oligomer that breaks into a monomer.<sup>[6]</sup> Breakdown of methacrylate group in Bis-GMA, which produces residual monomers. These residual monomers cause an increase in the surface roughness of the composite resin.<sup>[11]</sup> This degradation process results in soft matrices and microscopic holes, which cause loose fillings that become the entry point for carbonated drinks. These holes become larger as they are continuously exposed to an acidic pH environment, increasing surface roughness.<sup>[6]</sup>

Hence, frequently consuming low-pH carbonated drinks can increase the surface roughness, as demonstrated. Among the three groups, nanofilled composite resin samples immersed in carbonated drink A of pH 2.4 caused the highest increase in surface roughness value. The results of the study are similar to those of previous studies. A study by Phanestu and Syafiar<sup>[10]</sup> demonstrated an increase in the surface roughness of the nanofiller composite resin after immersion in black tea for 1, 2, 3, and 4 h. Study by Isabel et al.<sup>[11]</sup> demonstrated that Coca-Cola Coffee and black tea influence the surface roughness of resin composites. A study by Liliyan and Violetta<sup>[12]</sup> also demonstrated that soft drinks significantly affect the surface roughness of preheated nanohybrid composite resins after 15 days of immersion. This preliminary research on the effect of carbonated drinks with different low pH levels on the surface roughness of nanofilled composite resin was limited to using only two different types of carbonated drinks. Many other brands of

carbonated drinks have different pH levels, and they can affect the surface roughness of nanofilled composite resin. Further research can be conducted on immersion in other brands of low-pH carbonated drinks because carbonated drinks produced by different brands can have different pH levels and affect surface roughness.

## 5. Conclusion

Based on the results, it can be concluded that after 15 days of immersion in carbonated drinks with low pH levels, there was a significant increase in nano-filled composite resin surface roughness.

## Conflict of Interest

The authors declared that there is no conflict of interest.

## Acknowledgments

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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**How to Cite this Article:** Munisamy S, Siswomihardjo W, Sunarintyas S. The Effect of Carbonated Drinks with Different Low pH Levels on Surface Roughness of Nano-filled Composite Resin. *International Journal of Scientific Research in Dental and Medical Sciences*. 2024;6(2):55-59. <https://doi.org/10.30485/IJSRDMS.2024.458844.1584>.