Effects of immersion in mouthwash for different durations and with different ethanol concentrations on the surface roughness of nanohybrid composite resin

B M Yofarindra, M Damiyanti and E Herda*

Department of Dental Materials, Faculty of Dentistry, Universitas Indonesia, Jakarta, 10430, Indonesia

*E-mail: ellyza_herda@yahoo.com

Abstract. This study analyzed the effects of immersion in mouthwash with different ethanol concentrations and for different durations on the surface roughness of nanohybrid composite resin. Twenty-four specimens were divided into four treatment groups: 17% ethanol-containing mouthwash for 1.5 h, 26.9% ethanol-containing mouthwash for 1.5 h, 17% ethanol-containing mouthwash for 3 h, and 26.9% ethanol-containing mouthwash for 3 h. Surface roughness was then measured using a SJ301 Mitutoyo Surface Roughness Tester. One-way analysis of variance and Tukey's test showed significant differences \((p < 0.05)\) between the surface roughness of the control group and the 26.9% ethanol-containing mouthwash group. This study confirms that immersion in ethanol-containing mouthwash leads to an increase in the surface roughness of nanohybrid composite resin.

1. Introduction

Demands of direct aesthetic restoration materials have increased in recent years, whereas the use of amalgam as a restoration material has decreased [1]. Composite resin has been the preferred restoration material since the 1970s and is suitable for anterior and posterior teeth [2].

Composite resin comprises four components: organic polymer matrix, anorganic filler, coupling agent, and initiator accelerator system. Composite resin is classified on the basis of the size and shape of the particles and the distribution of the filler size. Types of composite resin include macrofilled, hybrid, microhybrid, and nanocomposite. Nanocomposite, the latest innovation in composite resin, resulted from the use of nanotechnology in filler development. Nanocomposite resin can be divided into two types, namely, nanofill and nanohybrid, and the particle size ranges from 1 to 100 nm. Clinical studies have shown that nanohybrid composite resin has a greater resistance to wear [3].

When composite resin is used in daily life, contact with other surfaces degrades the material and the surface becomes rough. Surface contact occurs through abrasion, attrition, and erosion processes [3-6]. Abrasion is wear caused by mechanical forces like friction between the restoration material and other materials, such as a hard toothbrush [7,8]. Attrition is wear caused by mastication forces and usually occurs in the incisal or occlusal planes of restoration materials [8]. Erosion is exposure of the restoration materials to chemicals such as a mouthwash [4-6].
Although the composition of mouthwash varies greatly, ethanol is typically one of the components. Ethanol has been used for oral hygiene and beauty for several centuries. Several studies have shown that mouthwash causes changes to the surface of composite resin, potentially because ethanol can accelerate hydrolytic degradation of resin-based materials. Rocha et al. reported that mouthwash with 21.6% ethanol increases the surface roughness of nanofill composite resin. Ozer et al. (2014) showed that composite resin solubility by mouthwash containing ethanol is greater than that of mouthwash without ethanol. Excessive solubility of restoration materials can lead to deformation of the surface and discrepancies of restoration margin. Ethanol contributes to increasing the surface roughness of composite resin by making the material become less rigid. In addition, the acidity of mouthwash contributes to surface degradation.

Although several studies of the effects of mouthwash on composite resin have been done, they did not control for the acidity of the mouthwash. Thus, the cause of the increased roughness cannot be clearly determined. Thus, a study of the effects of immersion in ethanol-containing mouthwash for varying durations on the surface roughness of nanohybrid composite resin that controls for acidity is needed. In previous work, the typical duration that teeth are exposed to mouthwash was assumed to be 1 min twice per day, that is, 2 min total per day. In this study, immersion times of 1.5 and 3 h thus represent 1.5 and 3 months of mouthwash use, respectively.

2. Methods
2.1 Measurement of mouthwash acidity
Two commercially available brands of mouthwash were used for this study: Frezza Strong Mint antiseptic mouthwash and Listerine Original antiseptic mouthwash. Prior to the start of the experiment, the acidity of each mouthwash was assessed three times using a pH meter.

2.2 Fabrication of resin specimens
A cylindrical mold with a diameter of 6 mm and height of 3 mm was prepared and smeared with silicone oil as the separating media. Nanohybrid composite resin (Filtek™ Z250 XT, shade A2, 3M ESPE, USA) was removed from the tube, placed on the mixing slab, and placed into the mold. A mylar strip was placed above the composite resin to result in a smooth surface. A 1 kg load was then placed on mold for 10 min, resulting in specimens with a flat surface. To avoid the influence of finishing techniques, the specimens were not polished.

2.3 Polymerization of specimens
The nanohybrid composite resin was polymerized with light emitting diode (LED) lighting for 20 s as recommended by the manufacturer. The distance between the tip of the LED unit was as small as possible (0 mm). This procedure was repeated 24 times to make 24 nanohybrid composite resin specimens.

2.4 Storage of specimens and measurement of initial surface roughness
The composite resin specimens were stored in Aqua Dest liquid at 37 °C (inside an incubator) for 24 h. The surface roughness values were then measured using a surface roughness tester.

2.5 Experimental groups
The specimens were randomly divided into four groups of six specimens and treated as follows: Group 1: Frezza Strong Mint for 1.5 h; Group 2: Frezza Strong Mint for 3 h; Group 3: Listerine Original for 1.5 h; and Group 4: Listerine Original for 3 h. After the immersion procedure, the specimens were rinsed using an ultrasonic cleaner.

2.6 Measurement of final surface roughness
After immersion in mouthwash, the surface roughness values of the composite resin specimens were determined using a surface roughness tester.

2.7 Statistical analysis
Statistical analysis was performed using parametric tests. One-way analysis of variance with Tukey's post hoc test was used to compare surface roughness values of the composite resin before and after immersion in mouthwash. Bonferroni correction was applied where appropriate.

3. Results
This study analyzed the effects of ethanol concentration and immersion time in mouthwash on the roughness of nanohybrid composite resin specimens. The acidity of the two mouthwash types were comparable, with Frezza Strong Mint mouthwash (17% ethanol) having a pH of 3.98 ± 0.03 and Listerine Original mouthwash (26.9% ethanol) having a pH of 4.19 ± 0.08.

Before immersion in mouthwash, the surface roughness of all specimens was measured to serve as a baseline. The mean surface roughness values of the specimens (expressed in Ra with µm units) are presented in Table 1.

Table 1. Average surface roughness of nanohybrid composite resin before and after immersion in mouthwash for 1.5 or 3 h.

| Immersion Time | Control 17% | Ethanol Concentration of Mouthwash 26.9% |
|----------------|-------------|-----------------------------------------|
| 1.5 h          | 0.104 ± 0.020 | 0.118 ± 0.021 | 0.123 ± 0.029 |
| 3 h            | 0.104 ± 0.020 | 0.119 ± 0.030 | 0.131 ± 0.028 |

As shown in Table 1, the average surface roughness values of the nanohybrid composite resin after immersion in mouthwash with 17% ethanol for 1.5 or 3 h were 0.118 ± 0.021 and 0.119 ± 0.030 µm, respectively. After immersion in mouthwash with 26.9% ethanol for 1.5 or 3 h the average surface roughness values were higher, i.e., 0.123 ± 0.029 and 0.131 ± 0.028 µm, respectively.

The difference in surface roughness before and after immersion in mouthwash with 26.9% ethanol for 1.5 h was statistically significant (P<0.05) (see Table 2). Similarly, the difference in surface roughness before and after immersion in mouthwash with 26.9% ethanol for 3 h was statistically significant (Table 3).

Table 2. Difference in surface roughness before and after immersion in mouthwash for 1.5 h.

| (I) Group          | (J) Group          | P Value |
|--------------------|--------------------|---------|
| Control            | Frezza (17%) 1.5 h | 0.162** |
|                    | Listerine (26.9%) 1.5 h | 0.029* |
| Frezza 1.5 hours   | Listerine (26.9%) 1.5 h | 0.982** |

*P<0.05
**P>0.05
Table 3. Difference in surface roughness before and after immersion in mouthwash for 3 h.

| (I) Group | (J) Group          | P Value |
|----------|--------------------|---------|
| Control  | Frezza (17%) 3 h   | 0.134** |
|          | Listerine (26.9%) 3 h | 0.000*  |
| Frezza, 3 hours | Listerine (26.9%) 3 h | 0.554** |

*P<0.05
**P>0.05

Table 4. Difference in surface roughness after immersion in mouthwash with varying ethanol concentrations for varying durations.

| (I) Group | (J) Group          | (p)     |
|----------|--------------------|---------|
| Frezza, 1.5 hours | Frezza (17%) 3 h   | 1.000** |
| Listerine, 1.5 hours | Listerine (26.9%) 3 h | 0.839** |

**P>0.05

Lastly, we tested if the surface roughness values differed after immersion in mouthwash with varying ethanol concentrations for varying durations. No significant differences were observed (Table 4).

4. Discussion
On the basis of the results of this study, the roughness of nanohybrid composite resin surfaces increased as immersion time in mouthwash increased. Roughness may increase because of effects of the liquid medium on the composite resin, such as water absorption and solubility [4]. The tendency of the composite resin to absorb water may be affected by the monomer type, urethane dimethacrylate (UDMA), bisphenol A-glycidyl methacrylate (Bis-GMA), and triethylene glycol dimethacrylate (TEGDMA) monomers have polar groups such as –OH, –O–, and –NH– that increase hydrophilicity, making them more susceptible to water absorption [11]. Bis-GMA has a higher water absorption value because it can form strong bonds with hydrogen in water molecules. The addition of TEGDMA may lead to increased water uptake in GMA-based resins [12]. These three monomers were contained in the nanohybrid composite resin used in this study.

Here, a significant change was observed in the surface roughness value before and after immersion in Listerine Original mouthwash, which has an ethanol concentration of 26.9%. Ethanol, which is a solvent contained in mouthwash, is known to accelerate hydrolytic degradation of resin-based materials [7]. This result is in line with findings from Luisa et al. [13] who reported that ethanol can affect the integrity of the surface of composite resin. The absorption of ethanol molecules into the resin matrix can cause softening of the composite surface. The ethanol molecules penetrating the matrix can cause the release of polymer structures, such as unreacted monomers, or cause the opening of polymer structures and result in absorption, which can increase wear to composite [14]. The penetration of ethanol into the polymer chain leads to expansion of the polymer structure, and so unreacted monomers break off and cause the linear chain of polymers to break. Expansion of the polymer chain occurs when the density of the crosslinking is low (weak) because the solvent can only damage secondary bonds, not the crosslinking [15]. Therefore, the significant result in our study may
be due to unreacted monomers and degradation effects on chain polymers, which usually occur in composite resin exposed to chemicals, water, ethanol, solvents, or acids, resulting in weak interactions between the polymer chains [4].

Besides ethanol, water is another factor that may have contributed to the increase in surface roughness after immersion [4]. Research by Sarveshwar et al. (2013) demonstrated that water can infiltrate and decrease the mechanical properties of a polymer matrix [16]. In general, composite resin contains an organic matrix that increases susceptibility to water absorption and surface disintegration in aqueous environments [11]. Hydrolytic degradation may occur in filler particles with a metal ionic composition. Metal ions contained in filler particles, such as zinc and barium, are electropositive and can react with water. The reaction keeps the elements in the filler disengaged and causes a balance change between the silica chain bonds contained in the filler. The loss of elements due to the reaction of metal ions with water creates an empty space that is then penetrated by hydrogen ions from the water. Increasing the hydroxy ion concentration causes bonds of siloxane (Si–O–Si) from silica to break down, and surface degradation cycles are formed. Increased surface roughness may thus be caused by loss of components from the material and the formation of gaps on the surface [17].

Interestingly, different effects were observed for immersion in Frezza Strong Mint mouthwash containing 17% ethanol. Although the roughness values did increase, the change was not statistically significant compared with the control values. Chemical composition, such as ethanol content, and duration of exposure are important variables and may affect polymer chain molecules; in other words, the longer the exposure to the chemical, the greater the adverse effect may be on the material [4]. Therefore, the lower ethanol concentration in Frezza Strong Mint mouthwash compared with Listerine Original mouthwash had a smaller effect on surface roughness.

Luisa et al. [12] studied the effects of beverages with various acidity levels on the roughness of nanohybrid composite resin. One of the beverages was acai juice, which had a pH of 4, and nanohybrid composite resin showed a significant difference in surface roughness after just 56 h of immersion in acai juice. In the current study, the pH values of Frezza Strong Mint and Listerine Original mouthwash were 3.98 ± 0.03 and 4.19 ± 0.08, respectively, which are not significantly different from the acidity (pH) of acai juice. The nanohybrid composite resin was only immersed in mouthwash for 1.5 and 3 h. Therefore, it is likely that the acidity (pH) of the mouthwash may have affected the increased roughness of the nanohybrid composite resin surface, but not significantly so.

The final surface roughness values, which indicated increasing surface roughness after immersion in mouthwash with differing ethanol concentrations, specifically were 17% and 26.9%. The roughness value increased as immersion time increased, even though it was not statistically significant because the difference in duration times was too short.

5. Conclusions
As the concentration of ethanol and the duration of immersion increased, the surface roughness value also increased. However, surface roughness was more affected by ethanol concentration than the duration of immersion.

References
[1] Mount G and Hume W 2005 Preservation and Restoration of Tooth Structure 2nd ed (Queensland: Knowledge Books and Software) p 200
[2] Anusavice K, Phillips R, Shen C and Rawls H 2003 Phillips’ Science of Dental Materials 11th ed (Philadelphia: Elsevier) pp 400–17
[3] Craig R 2012 Craig’s Restorative Dental Materials 13th ed eds R Sakaguchi and J Powers (Missouri: Elsevier) pp 163–81
[4] Rocha A, Lima C, Santos M and Montes M 2010 Evaluation of surface roughness of a nanofill resin composite after simulated brushing and immersion in mouthrinses, alcohol and water 
Mat. Res. 13 77–80 
[5] A M Ramadhani, E Herda and S Triaminingsih 2017 The effect of brushing with toothpaste containing nano calcium carbonate upon nanofill composite resin surface roughness J. Phys.: Conf. Ser. 884 012048 
[6] S Nuraini, E Herda and B Irawan 2017 Surface roughness of composite resin veneer after application of herbal and non-herbal toothpaste J. Phys.: Conf. Ser. 884 012048 
[7] Ozer S, Sen Tunc E, Tuloglu N and Bayrak S 2014 Solubility of two resin composites in different mouthrinses Biomed. Res. Int./ 2014 580675 
[8] Jain R and Hegde M N 2015 Dental attrition-Aetiology, diagnosis and treatment planning: a review. J. Dent. Med. Sci. 14 60–6 
[9] Toedt J, Koza D and Cleef-Toedt K 2005 Chemical Composition of Everyday Products (Westport) (Connecticut: Greenwood Press) p 48–9 
[10] Werner C and Seymour R 2009 Are alcohol containing mouthwashes safe? Br. Dent. J. 207 E19.488–9 
[11] McCabe J and Walls A 2008 Applied Dental Materials 9th ed (Oxford: Blackwell Publishing Ltd) pp 210–12. 
[12] Damiyanti M, Soufyan A, Kusuma E Y and Ditta S P 2014 Effect of Mangosteen (Garcinia mangostana) peel solution on human enamel surface color J. Med. Sci. (Faisalabad). 14 297–302 
[13] Gladwin M and Bagby M 2013 Clinical Aspects Of Dental Materials 4th ed (Philadelphia: Lippincott Williams & Wilkins) pp 65–67 
[14] Jain N and Wadkar A 2015 Effect of Nanofiller Technology on Surface Properties of Nanofilled and Nanohybrid Composites Int. J. Dent. Oral. Health. 1 1-5. 
[15] De Moraes R R, Gonçalves Lde S, Lancellotti A C, Consani S, Correr-Sobrinho L and Sinhoreti M A 2009 Nanohybrid resin composites: nanofiller loaded materials or traditional microhybrid resins? Oper. Dent. 34 551–7 
[16] Reddy P S, Tejaswi K S, Shetty S, Annapoorna B M, Pujari S C and Thippeswamy H M 2013 Effects of commonly consumed beverages on surface roughness and color stability of the nano, microhybrid and hybrid composite resins: an in vitro study J. Contemp. Dent. Pract. 14 718–23. 
[17] Noort R 2002 Introduction to Dental Materials 2nd ed (Edinburgh: Mosby) pp 96–97.