The effect of brushing with toothpaste containing nano calcium carbonate upon nanofill composite resin surface roughness

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Abstract. This study aims to determine the effect of brushing with toothpaste containing nanocalcium carbonate on the roughness of nanofill composite resin surface. Brushing was conducted with 3 types of materials for 3 consecutive brushing periods of 10 minutes each. Surface roughness was measured using a surface-roughness tester and the results were analyzed using the repeated ANOVA and the one-way ANOVA test. The surface morphology was observed using SEM after 3 months’ worth of brushing with the 3 materials. It was found that the nanofill composite resin surface-roughness value increased significantly (p<0.005) after brushing with toothpaste containing nano calcium carbonate for 3 months, but the value was not as high as that obtained when brushing with other types of toothpaste.

1. Introduction
Nano composite resin is used widely in dentistry because it offers a good level of wear-resistance and excellent aesthetic as it has the appearance of a real tooth. All the particles within nanofill composite resin are sized 1–100 nm, whereas nanohybrid composite resin contains particles of different sizes, some of which are as large as 0.4–5 microns [1]. A study by Oliviera et al. (2011) has shown that, after brushing with toothpaste, the surface-roughness value of nanofill composite resin is less than that of microhybrid composite resin. This is because of the smaller particle size of nanofill composite resin, which leads to the distribution of the filler being more homogeneous. As such, nanofill composite resin offers a better quality surface [2].

Nano technology has not only been developed for composite resin; there is also toothpaste available now that contains nano calcium carbonate. Research by Nakashima et al. (2008) has shown that toothpaste containing nano calcium carbonate contains very small nano calcium carbonate particles that measure tens of hundreds of nanometers [3]. Calcium carbonate is an abrasive agent used in several trademarked toothpastes. Variations in nano calcium carbonate particle size and roughness between toothpaste brands will lead to differences in the toothpastes’ ability to remove stains. It is also known that calcium carbonate can support remineralization [4]. Standard calcium carbonate contains larger particles than nano calcium carbonate (around 1 to 12 μm).

Brushing using toothpaste that contains an abrasive agent can affect the roughness of the surface of composite resin. Previous studies concerning the effects of several types of toothpaste upon composite resin surface roughness have demonstrated that brushing with toothpaste tends to increase the roughness of the surface of composite resin [2,5-7]. Other studies have shown that toothpaste containing nano calcium carbonate can increase tooth remineralization, thus having a positive effect...
upon early carious lesions [8,9]. Differences in daily toothpaste routines influence the levels of composite resin restoration. This study aims to determine the effects of using toothpaste containing nano calcium carbonate upon the surface roughness of nanofill composite resin.

2. Materials and Methods
This study is based upon experimental laboratory research conducted at the Research Laboratory Faculty of Dentistry, Universitas Indonesia and at the National Nuclear Energy Agency of Indonesia. Eighteen specimens were prepared in a cylindrical molds with a 6 mm diameter and a height of 3 mm. All the molds were covered with silicone oil. Nanofill composite resin (Filtek Z350 XT, 3M ESPE, USA) was condensed into each mold in 2 incremental procedures and then cured for 20 seconds with a light-curing unit (Hilux, Benlioglu, Europe). During the second incremental procedure, the composite resin surface was covered with mylar strips. A glass plate was then placed on top of the mylar strips and 1 kg weight was loaded on top, after which the specimens were cured. Then, the specimens were removed from the molds and stored in Aquabidest at 37°C for 24 hours.

Baseline roughness was measured using a surface-roughness tester (Mitutoyo SJ 301, Japan). Each specimen was measured 3 times, with the mean value for the 3 results being deemed the baseline surface-roughness value (Ra, µm). The cut-off value for the measurements was 0.25 µm, while the evaluation length was 0.75 µm. The specimens were divided randomly into three brushing groups. Each group consisted of six specimens. Brushing was performed using a toothpaste holder and an electric toothbrush, with a load of 175 g. The brushing was conducted for 10 minutes and repeated 3 times, which was assumed to be equal to brushing for 3 months altogether. In the experiment, two toothpastes were used: one containing nano calcium carbonate (Systema Nano™) and one containing standard calcium carbonate (Pepsodent for caries prevention™). The toothpaste was diluted first at a ratio of 1:1 (1 g toothpaste: 1 ml Aquabidest ). After each 10-minute brushing period, the surface roughness of the composite resin was measured (using the same approach taken when measuring baseline surface roughness).

A scanning electron microscope, or SEM (JSM 6510LA, JEOL, Japan), with a magnification of 1500 times was used to observe the surface morphology of the nanofill composite resin. The specimens were selected randomly for observation of the nanofill composite resin surface and the changes after 30 minutes of brushing. The mean values for the surface roughness of the nanofill composite resin were analyzed using the repeated ANOVA with post-hoc bonferroni in order to determine the differences between the composite resin roughness values before and after brushing. The comparative one-way ANOVA test with post-hoc bonferroni was conducted in order to establish the differences between the roughness values for the three treatment groups.

3. Results and Discussion
3.1 Results
The changes in the roughness values for the nanofill composite resin can be seen in Table 1. The roughness values for the nanofill composite resin increased in all the brushing groups. The greatest increase occurred in the group in which calcium carbonate toothpaste was used, followed by the group in which the nano calcium carbonate toothpaste was used. The lowest increase occurred in the Aquabidest group (no toothpaste). Figure 1 demonstrates the changes.

The increase in the mean surface-roughness value for the Aquabidest group (no toothpaste) after brushing for 30 minutes, which was assumed to be equivalent to 3 months’ brushing daily, was significant, with a p value of < 0.005 (p=0.037). For the nano calcium carbonate toothpaste and standard calcium carbonate toothpaste groups, the changes were significant after 10 minutes of brushing, assumed to be equivalent to 1 month of brushing daily (p=0.014 and p=0.029, respectively). Furthermore, when comparing the two different toothpastes, the difference in the surface-roughness values was significant (p=0.002) after brushing for 30 minutes.
Table 1. Mean values of nanofill composite resin surface roughness

| Brushing Agent                        | 0 minutes (µm ± SD) | 10 minutes (µm ± SD) | 20 minutes (µm ± SD) | 30 minutes (µm ± SD) |
|---------------------------------------|---------------------|----------------------|----------------------|----------------------|
| Aquabidest (no toothpaste)            | 0.13±0.01           | 0.17±0.03            | 0.23±0.05            | 0.24±0.05            |
| Nano calcium carbonate toothpaste     | 0.13±0.01           | 0.28±0.06            | 0.36±0.04            | 0.42±0.04            |
| Calcium carbonate toothpaste          | 0.13±0.01           | 0.30±0.08            | 0.45±0.09            | 0.55±0.05            |

A back-scattered SEM was used to observe the surface morphology changes of the nanofill composite resin before and after brushing with Aquabidest, nano calcium carbonate toothpaste, and standard calcium carbonate toothpaste, as depicted in Figure 1. In part A of the figure, the filler seems to be almost completely covered by a matrix. Part B shows the specimens brushed with Aquabidest for 30 minutes. Here, the filler looks clearer and is porous due to the entrapment of air during the composite-resin processing. The specimen surface also looked a little rougher than in part A. In part C—the specimen brushed using nano calcium carbonate toothpaste for 30 minutes—there are some concave areas caused by unattached filler particles. The filler component seems larger here and the surface is rougher than in parts A and B. In part D—the specimen brushed with calcium carbonate toothpaste for 30 minutes—the shape of the filler seems much clearer than in parts A, B, and C. Here, the specimen surface seems to be characterized by larger and clearer filler particles, when compared with the particles visible in parts A, B, and C.

Figure 1. Micrograph photograph of nanofill composite resin specimens at a magnification of 1500 times. A: specimen before brushing. B: specimen after brushing for 30 minutes with Aquabidest. C: Specimen after brushing for 30 minutes with SystemaNano™. D: Specimen after brushing for 30 minutes with regular Pepsodent.™

3.2 Discussion
The results of this experimental study show that the surface-roughness values for composite resin increase after brushing with Aquabidest, nano calcium carbonate toothpaste, and standard calcium carbonate toothpaste for 30 minutes, as shown in Table 1. A load of 175 g was used, a quantity which led to significant changes in surface roughness. It can be hypothesized that a larger load would
increase the surface roughness of composite resin further. Brushing using Aquabidest alone (no toothpaste) has been shown to increase the surface roughness of nanofill composite resin. The increase after 30 minutes (assumed to be equal to brushing for 3 months) was significant. Where toothpaste containing nano calcium carbonate and standard calcium carbonate was concerned, the results were significant after 10 minutes of brushing (assumed to be equal to brushing for 1 month). When comparing the effects of the two types of toothpaste, the surface roughness of the composite resin differed significantly after 30 minutes of brushing time.

The surface roughness of the nanofill composite resin increased after brushing with Aquabidest (without toothpaste) for 30 minutes due to friction between the composite resin surface and the electric toothbrush, leading to the composite resin surface abrading. It is known that a bristled brush can lead to the abrasion of the surface of composite resin, but the effect is smaller than that of the combination of a bristled brush and an abrasive agent [10]. Our results differ from those of Suzuki et al. (2012), who found that brushing composite resin with water did not increase surface roughness [11]. The variations in the results may be due to differences in the baseline surface-roughness surface value of the composite resin; in Suzuki et al.’s study, the early roughness value was 0.04 µm, whereas the early roughness value in this study was 0.13 µm. A low early surface roughness can prevent the matrix on the composite resin from being abraded [11]. This can be seen in Figure 1, in which the composite resin matrix has begun to be abraded by brushing with Aquabidest, but the result is less extreme than the results obtained by brushing with toothpaste. An important factor here is the bristles of the brush, which can influence the surface-roughness values achieved. A larger number of bristles and/or a harder type of bristle can lead to greater abrasion of the surface of the composite resin.

The surface roughness of the composite resin was at the greatest after brushing with toothpaste containing calcium carbonate. This can be said to be due to contact with a more abrasive agent, causing the composite resin surface to be abraded to a higher degree. The differences between the particle sizes in the abrasive agents have an effect here—while nano calcium carbonate particles measure tens of hundreds of nanometers, standard calcium carbonate particles are sized from 1 to 12 µm. [3] The use of an abrasive agent with larger particles thus increases levels of abrasion [12]. The SEM results for the specimens, shown in Figure 1, indicate the variations in particle size. The filler particles can be seen more clearly in the specimen brushed with calcium carbonate than in the specimen brushed with Aquabidest. The friction caused by the brush and the abrasive agent degrades the matrix on the surface of the composite resin, thus leaving the filler exposed. There are also differences between the specimens brushed with the two different types of toothpaste—the larger the abrasive particles, the more visible the filler particles.

Similar mechanisms are responsible for the increases in the surface-roughness values for the toothpaste containing nano calcium carbonate and the toothpaste containing calcium carbonate. In both cases, the brush and the abrasive agent work together to abrade the surface of the nanofill composite resin. Each particle in the abrasive agent has a sharp tip that is able to cut a material surface. These sharp tips occur because of the irregular shapes of the particles in the abrasive agents [12]. These results regarding increasing levels of surface roughness on composite resin after brushing accord with several previous studies that show how composite resin becomes rougher after brushing with several types of toothpaste [2,5-7]. It should also be noted, however, that there is a less pronounced effect when using nanofill composite resin, compared with using other types of composite resin, according to existing research [2].

The surface-roughness value can affect a patient’s level of comfort. Composite resin with a surface-roughness value of more than 1 µm can make patients feel uncomfortable because the roughness is detectable by the tongue [13]. In addition, composite resin with a surface-roughness value of more than 0.2 µm can also lead to plaque and bacteria retention in the mouth [14]. In the present study, the surface roughness of nanofill composite resin remained at an acceptable level when the resin was brushed with Aquabidest. When brushing with toothpaste containing nano calcium carbonate or standard calcium carbonate, there was a more pronounced increase in the roughness of the resin surface, but the level did not reach 1 µm. Although the use of calcium carbonate (with a
vidence of 3 Mohs) as an abrasive agent in toothpaste raises the roughness level of composite resin, then, the level is not extreme and such toothpastes can therefore be used daily [15]. The use of toothpaste has several advantages for oral health. In particular, toothpaste containing nano calcium carbonate have been proven to increase remineralization rates, thus helping to prevent early carious lesions (in as little as 2 weeks) [3,8,9]. The brush type also needs to be considered. The selection of softer bristles can lead to a decrease in abrasion levels. Here, it can be suggested that the use of gentle pressure combined with an abrasive agent is the most prudent approach.

4. Conclusion

The results of the present study indicate that the surface roughness of nanofill composite resin is affected by the size of the abrasive agent particles within a toothpaste. Brushing with a toothpaste containing nanocalcium carbonate increases the roughness of the surface of nanofill composite resin, and brushing with a toothpaste containing standard calcium carbonate leads to even greater rates of surface roughness.

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