The effect of toothbrush bristle stiffness on nanohybrid surface roughness

O Zairani, B Irawan and M Damiyanti*
Department of Dental Materials, Faculty of Dentistry, Universitas Indonesia, Jakarta, Indonesia
E-mail: miadamiyanti@gmail.com

Abstract. The surface of a restoration can be affected by toothpaste containing abrasive agents and the stiffness of toothbrush bristles. Objective: To identify the effect of toothbrush bristle stiffness on nanohybrid surface roughness. Methods: Sixteen nanohybrid specimens were separated into two groups. The first group was brushed using soft-bristle toothbrushes, and the second group was brushed using medium-bristle toothbrushes. Media such as aqua bides was used for brushing in both groups. Brushing was done 3 times for 5 minutes. Surface roughness was measured initially and at 5, 10, and 15 minutes using a surface roughness tester. Results: The results, tested with One-Way ANOVA and Independent Samples t Test, demonstrated that after brushing for 15 minutes, the soft-bristle toothbrush group showed a significantly different value \( p < 0.05 \) of nanohybrid surface roughness. The group using medium-bristle toothbrushes showed the value of nanohybrid surface roughness significant difference after brushing for 10 minutes. Conclusion: Roughness occurs more rapidly when brushing with medium-bristle toothbrushes than when brushing with soft-bristle toothbrushes.

1. Introduction
Oral health has not become a priority for Indonesian society. Many Indonesian people have dental problems such as caries and periodontal disease. Data from National Basic Health Survey 2007 and 2013 shows the increase of prevalence of dental health problems in Indonesia from 23.5% to 25.9%. The most common dental health problem is dental caries \([1,2]\).

Based on Blum’s theory, the status of a person’s oral health is influenced by four important factors, heredity, physical environment and culture, lifestyle, and medical care. However, the most important factor influencing a person’s oral health is lifestyle \([3]\). Caries is caused by the interaction of multiple factors including the societal habit of regularly consuming sweets and irregularly maintaining dental hygiene by tooth brushing. When dental caries appears, the treatment is restoration. Restoration is performed based on the damage to a tooth. Extensive damage to a tooth can be restored with inlay or onlay, while damage to a tooth that extends only as far as enamel or dentin can be restored with glass ionomer cements and composite resin.

Composite resin is a restorative material widely used by dentists that has the same colour as teeth. The use of composite resin continues to develop; currently the filler of composite resin is the size of a nano meter. That composite resin consists of nanofil and nanohybrid. Composite resin with nanometer sized has great aesthetic results and good wear resistance. However, the wear resistance is influenced by erosion and abrasion which cause changes on the composite resin’s surface called surface roughness \([4]\).
Surface roughness is an irregularity of surface due to a material or process. Factors that affect the surface roughness of restorative material are finishing polishing procedures and tooth brushing. One of those factors is tooth brushing with a toothbrush and toothpaste. Wear on material surface may occur when combination of abrasive toothpaste and hard toothbrush bristles is used [4,5].

The components of a toothbrush include the handle, the neck, the head, and the bristles. Of all the components, the bristles are the most important because they directly touch the tooth surface. The stiffness of toothbrush bristles depends on diameter, length of filament, and toothbrush elasticity. Based on the stiffness of the toothbrush bristles, toothbrushes are divided into soft bristles, medium bristles, and hard bristles [4,6].

The stiffness of toothbrush bristles can impact the surface roughness of restorative materials. Based on previous studies, the effect of different toothbrush bristles' stiffness on the surface roughness of restorative materials showed that bristles have an abrasive effect on composite resin but that the effect was smaller compared to the abrasive effect caused by a combination of bristles and abrasive materials [7,8,9].

A study about the effect of abrasive toothpaste and toothbrush bristles of different diameters (0.15 mm, 0.20 mm, 0.25 mm) on dentin which has been soaked by acid, showed that toothbrush bristles had an abrasive effect on the surface of resin composite but that the effect was smaller compared to the combination of toothbrush bristles and toothpaste with abrasive materials [7]. Another study about the abrasion and roughness of hybrid and nanohybrid composite resin after being brushed with toothpaste and toothbrushes of varying bristle stiffness showed that surface roughness increased as the amount of brushing increased and that the stiffness of toothbrush bristles had a small effect on surface roughness [8]. Another study about the abrasion and roughness of hybrid and nanohybrid composite resin after being brushed with toothpaste and toothbrushes of varying bristle stiffness showed that surface roughness increased as the amount of brushing increased and that the stiffness of toothbrush bristles had a small effect on surface roughness [8]. Another study about the abrasion and roughness of hybrid and nanohybrid composite resin after being brushed with toothpaste and toothbrushes of varying bristle stiffness showed that surface roughness increased as the amount of brushing increased and that the stiffness of toothbrush bristles had a small effect on surface roughness [8].

The purpose of this study is to examine the effect of toothbrush bristle stiffness on the surface roughness of nanohybrid composite resin.

2. Materials and Methods

This study was conducted in an experimental laboratory. The specimens of composite resin used in this study were nanohybrid composite resin Filtek™ Z250 XT (3M ESPE, USA) shade A3 in a cylindrical shape with a diameter of 6 mm and a height of 3 mm. The total number of specimens was 16, divided into 2 groups with 8 specimens in each group.

The first step is preparation composite resin specimens. Metal mold 6 mm x 3 mm in cylindrical shape was coated with silicon oil. Nanohybrid composite resin was put into the mold using plastic filling. A mylar strip was used to cover the composite before it was flattened by prepared glass and a 1 kg weight. The specimen was light cured using light-emitting diode curing unit Hilux Ledmax with an intensity of 600 mW/cm² for 20 seconds. After light curing, the mylar strip was removed, and the specimen was taken out of the mold. The excessive part of the specimen was removed. The specimen was then stored in a clean and dry compartment. The steps were repeated for 16 specimens. Specimens were then soaked in aqua bides for 24 hours and in an incubator with a temperature of 37°C.

Second step is measurement of initial roughness value with surface roughness tester Mitutoyo SJ 301 with cut-off length 0.25 mm (N = 5) and evaluation length 1.25 mm. Specimens were put on prepared glass, and then fixated in flat and immobile positions with plasticin. The specimens were positioned with the stylus on the top of specimen. The measurement of initial roughness was conducted at 3 different points. The result was recorded, and the mean value was counted to get the initial roughness of the specimens.

The composite resin specimens were divided into 2 groups, each containing 8 specimens. Brushing was conducted in both groups. Brushing in the first group was done with electric toothbrushes with soft bristles, while brushing in the second group was done with electric toothbrushes with medium
bristles. In both groups, aquabides were used as media of brushing without toothpaste. The electric toothbrushes with soft bristles (Trisa Sonic Power Battery Operated Electric Toothbrush Junior Soft, Germany) had the following characteristics: toothbrush head was 2.2 cm x 1 cm (length x width), bristles were arranged into 27 chains (one chain contained 60 filaments), the length of bristles was 10 mm, and the diameter of bristles was 0.10 mm. The electric toothbrushes with medium bristles (Trisa Sonic Power Battery Operated Electric Toothbrush Medium, Germany) had the following characteristics: toothbrush head (medium) was 3 cm x 1 cm (length x width), bristles were arranged into 38 chains (one chain contained 60 filaments), the length of bristles was 10 mm, and the diameter of bristles was 0.12 mm. Both types of electric toothbrushes (soft and medium bristles) were ISO standardized and vibrate 20,000 vpm (vibration per minute). The movement of both types of brushes was vibration when it was used horizontally so it could clean efficiently between teeth and areas that were usually difficult to clean. For both brushes, the head of the toothbrush was changeable, the bristles were made from nylon with end-rounded bristles, the handle was made from polymer, and the brushing technique was Bass (aiming the bristles at the gum in a 45-degree angle similar to the manual toothbrush technique).

Third step is specimen brushing and measurement roughness value after brushing. The surface of each specimen that has been coated by mylar strip at the time of polymerization was brushed 3 times, each time for 5 seconds. The brush touched all of this surface on each specimen. The amount of brushing was assumed to represent 3 months of brushing one day for 5 seconds. This was determined using the mean time of brushing for 2 minutes or 120 seconds twice daily divided by the number of teeth inside the mouth. Brushing for one month (30 days) was 5 minutes so that the sum of 3 months of brushing was 15 minutes. Toothbrushes were changed for every specimen. The load for brushing was 200 grams [8]. After brushing was complete, the specimens were rinsed with water and dried. The surface roughness was then measured. The measurement was done 3 times and repeated after brushing for 5 minutes.

The results of this study were analyzed statistically using parametric test One-Way ANOVA with post hoc Bonferroni to determine the difference of the roughness value between the nanohybrid composite resin surface before and after brushing. Data was also analyzed using Independent Samples T Test to determine if there was a difference between the composite resin surface that was brushed with soft bristles and medium bristles.

3. Results and Discussion

3.1 Results

The surface roughness measurements of nanohybrid composite resin after being brushed with aquabides as the medium and electric toothbrushes with soft and medium bristles for the first 5 minutes, the second 5 minutes, and the third 5 minutes is presented in Table 1.

The results of this study showed that there was an increase in nanohybrid composite resin surface roughness after brushing with electric toothbrushes with either soft bristles or medium bristles for the first 5 minutes (5 minutes was assumed to equal 1 month), the second 5 minutes (10 minutes was assumed to equal 2 months), and the third 5 minutes (15 minutes was assumed to equal 3 months). The measurements of composite resin roughness in Table 1 which show an increase in roughness with brushing are presented in graphic form in Figure 1. One-Way ANOVA with post hoc Bonferroni was used to compare the surface roughness of nanohybrid composite before and after brushing (5 minutes, 10 minutes, 15 minutes) in each group.

In the soft-bristle group, the surface roughness did not show any significant difference between the initial measurement and the measurement after 5 minutes of brushing or 10 minutes of brushing, with significant value of $p > 0.05$ ($p = 1.000$). However, the comparison between the initial measurement and the measurement after 15 minutes of brushing showed a significant difference, with significant value of $p < 0.05$ ($p = 0.022$). The measurement of surface roughness after 5 minutes of brushing compared to 10 minutes of brushing and 15 minutes of brushing and the comparison between 10 minutes of brushing and 15 minutes of brushing did not show any significant difference, with
significant value of $p > 0.05$ ($p = 1.000$, $p = 0.100$, and $p = 0.523$). These data values are presented in Table 2.

In the medium-bristle group, the value of surface roughness did not show a significant difference between the initial measurement and the measurement after 5 minutes of brushing, with significant value of $p > 0.05$ ($p = 0.068$). Comparison between the initial measurement and the measurement after 10 minutes and 15 minutes of brushing showed a significant difference, with significant value of $p < 0.05$ ($p = 0.000$). A significant difference was shown in the 5-minute measurement compared to the 15-minute measurement, with significant value of $p = 0.002$. The comparison of surface roughness after 5 minutes of brushing compared to 10 minutes of brushing did not show any significant difference. Likewise, there was no significant difference between 10 minutes of brushing and 15 minutes of brushing with the medium bristles, with significant value of $p > 0.05$ ($p = 0.323$ and $p = 0.441$). These values are presented in Table 3.

The study results were also analyzed with the Independent Samples t Test to compare the surface roughness of nanohybrid composite between the two groups. After 5 minutes of brushing, no significant difference was shown between the groups of soft bristles and medium bristles, with significant value of $p > 0.05$ ($p = 0.058$). Meanwhile after 10 minutes of brushing and 15 minutes of brushing, there was a significant difference between the soft bristles and medium bristles, shown by the significant value of $p < 0.05$ ($p = 0.006$ and $p = 0.048$). These values are presented in Table 4.

**Table 1. Mean Value of Measurement of Nanohybrid Composite Resin Surface Roughness**

| Tools and Materials for Brushing | Surface Roughness Value (Ra, μm) |
|----------------------------------|----------------------------------|
|                                  | Initial (μm ± SD) | 5 minutes (μm ± SD) | 10 minutes (μm ± SD) | 15 minutes (μm ± SD) |
| Electric toothbrush with soft bristles | 0.16 ± 0.02 | 0.17 ± 0.02 | 0.18 ± 0.01 | 0.21 ± 0.02 |
| Electric toothbrush with medium bristles | 0.16 ± 0.02 | 0.20 ± 0.02 | 0.22 ± 0.02 | 0.25 ± 0.02 |

**Figure 1.** Graphic of Increase Value of Measurement of Nanohybrid Composite Resin Surface Roughness
Table 2. Values from Statistical Comparative Test ANOVA Brushing with Electric Toothbrush with Soft Bristles

| Comparison                  | p-value |
|-----------------------------|---------|
| Initial-Brushing 5 min      | 1.000   |
| Initial-Brushing 10 min     | 1.000   |
| Initial-Brushing 15 min     | 0.022   |
| Brushing 5 min-10 min       | 1.000   |
| Brushing 5 min-15 min       | 0.100   |
| Brushing 10 min-15 min      | 0.523   |

Table 3. Values from Statistical Comparative Test ANOVA Brushing with Electric Toothbrush with Medium Bristles

| Comparison                  | p-value |
|-----------------------------|---------|
| Initial-Brushing 5 min      | 0.068   |
| Initial-Brushing 10 min     | 0.000   |
| Initial-Brushing 15 min     | 0.000   |
| Brushing 5 min-10 min       | 0.323   |
| Brushing 5 min-15 min       | 0.002   |
| Brushing 10 min-15 min      | 0.441   |

Table 4. Value of Statistical Independent Sample t Test

| Comparison                  | p-value |
|-----------------------------|---------|
| Group A-Group B (after 5 min)| 0.058   |
| Group A-Group B (after 10 min)| 0.006  |
| Group A-Group B (after 15 min)| 0.048  |

Details. Group A: Electric toothbrush with soft bristles. Group B: Electric toothbrush with medium bristles.

3.2 Discussion
The results showed that brushing with soft and medium bristles for 5 minutes, 10 minutes, and 15 minutes increased the surface roughness of nano hybrid composite resin. This study used a load of 200 grams while brushing. Based on ISO/TR 14569-1, the 200 grams load was the factor that caused the increase of nanohybrid surface roughness [8].

Brushing with soft bristles showed a significant difference after brushing for 15 minutes compared with the initial value. A significant difference was also shown after brushing with medium bristles for 10 and 15 minutes compared with the initial value as well as brushing for 5 minutes when compared to brushing for 15 minutes. Brushing for 5 minutes was assumed to be equivalent to brushing for 1 month, brushing for 10 minutes was assumed to be the equivalent of brushing for 2 months, and...
brushing for 15 minutes was assumed to be the equivalent of brushing for 3 months. When the two toothbrushes were compared, a significant difference was seen after brushing for 10 minutes and 15 minutes.

An increase in surface roughness was seen after brushing with soft bristles. After 5 minutes and 10 minutes of brushing there was no significant difference. However, a significant difference was seen after 15 minutes of brushing compared with the initial value. This corresponds with a previous study on the difference of abrasion and roughness of hybrid and nanohybrid composite resin after brushing with toothpaste and after brushing with toothbrushes with different stiffness (soft, medium, and hard). The measurement of roughness was performed 5 times. The amount of rotation on one measurement was 10,000 rotations which was equivalent to 1 year of brushing. The results showed that brushing with soft bristles increased the roughness value. Increased brushing time causes scrapes on the matrix causing filler particles to fall out of the bond between matrix and filler. This results in irregularities on the surface of composite resin. The longer the brushing, the more filler will fall out of the bond causing the surface to be rougher [8].

Brushing with medium bristles also caused an increase in surface roughness. There was no significant difference after 5 minutes of brushing. However, a significant difference was seen after 10 minutes and 15 minutes of brushing compared to the initial value and between 15 minutes of brushing compared to 5 minutes of brushing. This result is supported by a study that showed increased surface roughness with increased brushing time [8]. Another study on the effect of soft and medium bristles on gingival abrasion showed that toothbrushes with medium bristles caused more gingival abrasion than toothbrushes with soft bristles. Composite resin when brushed becomes abraded. This happens because the structure of soft bristles is thinner and more flexible than medium bristles, and a wider area is brushed with medium bristles. The wider the area being brushed, the wider the area that is abraded [10].

This study used the same nylon, end-rounded tip, and a bristle length of 10 mm as the previous study [10]. However, in this study, the heads of the soft-bristle toothbrushes were 2.2 cm x 1 cm (length x width) with bristles arranged into 27 chains (one chain contained 60 filaments) with a bristle length of 10 mm, and a bristle diameter of 0.10 mm. The heads of the medium-bristle toothbrushes were 3 cm x 1 cm (length x width) with bristles arranged into 38 chains (one chain contained 60 filaments) with a bristle length of 10 mm, and a bristle diameter of 0.12 mm. Also, this study was conducted with aqua bides without toothpaste. In the previous study, the heads of the soft- and medium-bristle toothbrushes were 2.5 cm x 1 cm (length x width), and both brushes were arranged into 43 chains (one chain consisted of 23 filaments). The diameter of one filament of soft bristles was 0.22 mm while the medium bristle diameter was 0.23 mm [10]. In the present study, roughness caused by abrasion appeared faster after being brushed with medium bristles than with soft bristles when compared to the initial value. This is similar to the previous study without toothpaste that showed abrasion caused by medium bristles was more significant (15% of percentage) than abrasion caused by soft bristles (8% of percentage) when compared to the initial value (5% of percentage) [10].

A significant difference in surface roughness between brushing with soft bristles and medium bristles was seen after 10 and 15 minutes of brushing. This result is supported by a study that compared surface roughness on enamel and nano hybrid composite resin caused by different types of electric toothbrushes (medium bristles, soft bristles, flat trim, and zig-zag). The study showed that brushing with medium bristles caused a rougher surface than brushing with soft bristles. The difference was caused by the structure of medium bristles that are thicker and stiffer than soft bristles. The medium bristles caused more matrix to be abraded and more fillers to fall out which then caused irregularities on the surface of nanohybrid composite resin [10,11].

After 5 minutes of brushing in both soft- and medium-bristle groups, no significant difference was shown. The surface of composite resin was considered rough if fillers fell out of the matrix-filler bond. In this study, after 5 minutes of brushing, the matrix had been degraded but not many filler particles fell out of the bond. The time to achieve surface roughness was not great enough.
Some studies have stated that multiple factors of brushing can influence surface roughness. These factors include brushing technique, load during brushing, duration and frequency of brushing, and type and stiffness of bristles. The stiffer of bristles, the more they will abrade a restoration's surface. However, bristles on a toothbrush alone generally have little abrasive effect. Toothpaste that contains abrasive materials can also increase surface roughness. Using a toothbrush with stiffer bristles combined with abrasive toothpaste can increase surface roughness more than using stiffer bristles alone [4,8,11].

Surface roughness of restorative material caused by chemical or mechanical factors can impact a patient’s esthetic smile and comfort by increasing plaque and bacterial retention, gingival irritation, secondary caries risk, and discoloration [8]. Based on a study about bacterial retention and the limit of surface roughness of some materials, the limit of composite's surface roughness that could lead to bacterial retention was 0.2 μm. More than that value, the restoration's surface has a higher potential for plaque and bacterial retention [12].

In this study, the surface roughness of nanohybrid composite that was brushed with soft bristles after 5 minutes of brushing and 10 minutes of brushing still had a good limit, 0.17 μm and 0.18 μm, respectively. However, after 15 minutes of brushing, the roughness value was 0.21 μm, which was a little higher than the limit of 0.2 μm. The surface roughness of nanohybrid composite which was brushed by medium bristles for 5 minutes had a good limit of 0.2 μm. Brushing for 10 minutes and 15 minutes showed surface roughness of 0.22 μm and 0.25 μm, making the composite rougher and more vulnerable to plaque and bacterial retention.

Toothbrushes with both soft and medium bristles if used for daily brushing can cause changes to tooth surface, especially surface roughness when combined with abrasive toothpaste. Caution must be taken regarding duration of brushing and brushing load when using toothbrushes long-term. If a toothbrush is used long-term with a big load while brushing, a toothbrush with medium bristles can cause surface roughness on composite resin faster than a toothbrush with softer bristles. The experiment in this study was different than oral conditions where there is protection such as saliva. To limit the abrasive effect of brushing on a restoration in an oral cavity, a toothbrush needs to be changed every 3 months, the load of brushing should not be excessive, and the right type of toothbrush and toothpaste should be chosen.

4. Conclusion
Brushing with either soft-bristle or medium-bristle toothbrush can increase the surface roughness of nanohybrid composite resin. Brushing with soft bristles can cause significant changes in surface roughness of nanohybrid composite resin after 15 minutes of brushing (assumed to equal 3 months). Meanwhile, brushing with medium bristles can cause a significant change in surface roughness after 10 minutes of brushing (assumed to equal 2 months). Brushing with both soft and medium bristles are used continously for 15 minutes (assumed t equal 3 months) can cause surface roughness and increase the potential of plaque and bacterial retention.

Both soft- and medium-bristle toothbrushes are safe for daily brushing. However, brushing with medium bristles long-term should be done with caution. Further study needs to be conducted about the effect of bristle stiffness on several kinds of composite resin to compare the surface roughness. Microstructure images should be taken to analyze the microstructure of the toothbrush bristles’ morphologies as well as the morphology of the restorative materials’ surfaces before and after treatment using scanning electron microscope (SEM).

References
[1] Badan Penelitian dan Pengembangan Kesehatan 2007 Riset Kesehatan Dasar (RISKESDAS). Lap Nas 2007 p17.
[2] Badan Penelitian dan Pengembangan Kesehatan 2013 Riset Kesehatan Dasar (RISKESDAS) 2013. In: Laporan Nasional 2013 pp 11–2.
[3] Anitasari S and Rahayu NE 2005 Hubungan frekuensi menyikat gigi dengan tingkat kebersihan
The 1st Physics and Technologies in Medicine and Dentistry Symposium

IOP Conf. Series: Journal of Physics: Conf. Series 884 (2017) 012008
doi:10.1088/1742-6596/884/1/012008

4. Sakaguchi RL and Powers JM 2012 Craig’s Restorative Dental Materials. 13th ed. (Philadelphia: Mosby Elsevier) p 50, 161-170, 175-178
5. Anonym 2016 Surface Roughness Tester [Internet] [cited 2016 Dec 1]. Available from: http://www.alatuji.com/kategori/113/roughness-tester
6. ISO 8627 1987 Dentistry-Stiffness of the Tufted Area of Toothbrushes. International Standard Organization.
7. Wiegand A, Kuhn M, Sener B, Roos M and Attin T 2009 Abrasion of eroded dentin caused by toothpaste slurries of different abrasivity and toothbrushes of different filament diameter. J. Dent. 37 480–4.
8. Kyoizumi H, Yamada J, Suzuki T, Kanehira M, Finger WJ and Sasaki K 2013 Effects of toothbrush hardness on in vitro wear and roughness of composite resins. J. Contemp. Dent. Pract. 14 1137–44.
9. Bizhang M, Riemer K, Arnold WH, Domin J and Zimmer S 2016 Influence of bristle stiffness of manual toothbrushes on eroded and sound human dentin - an in vitro study. PLoS One 11 1–13.
10. Zanatta FB, Bergoli AD, Werle SB and Antoniazi RP 2011 Biofilm removal and gingival abrasion with medium and soft toothbrushes. Oral Health Prev. Dent. 9 177–83.
11. Dabhi MV, Kishan KV and Shah S 2016 Comparative Evaluation of Three Different Types of Tooth Brush on Surface Abrasion of Enamel & Nanohybrid Composite - An in Vitro Study. J. Dent. Med. Sci. 15 122–7.
12. Bollen CM, Lambrechts P and Quirynen M 1997 Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: a review of the literature. Dent. Mater. Off Publ. Acad. Dent. Mater. 13 258–69.