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Research Report

Surface roughness of nanofilled and nanohybrid composite resins exposed to kretek cigarette smoke

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ABSTRACT

Background: *Cigarette smoking is a public health issue that may influence the physical properties of dental composites. Surface roughness is one of the physical properties of restorative materials potentially influencing their success. The use of nanofilled and nanohybrid composites in dentistry has increased substantially over the past few years.* ***Purpose:*** *The purpose of this study was to evaluate the surface roughness of nanofilled and nanohybrid composite resins exposed to kretek cigarette smoke.* ***Methods:*** *Twelve cylindrical specimens of each material were prepared and divided into two groups (n=6). In the control groups, the specimens were immersed in distilled water for 24 hours at 37°C, with the water being renewed daily. For the experimental groups, the specimens were exposed to kretek cigarette smoke on a daily basis, then washed and soaked in distilled water at 37°C. After 21 days, the specimens were measured using a Surface Roughness Tester and the data was then statistically analyzed.* ***Results:*** *An Independent-T Test revealed that there were statistically significant differences in the surface roughness between the control and experimental groups of both nanofilled and nanohybrid composites, as well as between the nanofilled experimental group and the nanohybrid experimental group.* ***Conclusion:*** *Exposure to kretek cigarette smoke can increase the surface roughness of nanohybrid composites to a significantly greater extent than nanofilled composites.*

Keywords: *composite resin; nanofilled; nanohybrid; surface roughness; kretek cigarette smoke*

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INTRODUCTION

Composite resin is one of the most widely used restorative materials in dentistry. Nano composite resin is the newest composite resin with smaller filler sizes (1-100 nanometers) and increased filler concentration. Thus, its physical, mechanical and esthetic properties are greatly enhanced.[1] There are two kinds of nano composite resin, namely nanofilled composite (all fillers with nano size) and nanohybrid composite (partially nano fillers and micro fillers).[2]

Nevertheless, the properties of composite resin as a restorative material may still be affected by several factors, including: matrix composition, filler, coupling agent and bonding techniques, among others.[3] Individual lifestyles, such as a smoking habit, can also affect the properties of the restorative material.[4]

Smoking is a public health problem commonly found within communities. According to WHO data, after China and India, Indonesia has the largest number of smokers in the world. A statistic which, unfortunately, is increasing from year to year. According to Riskesdas (National Basic Health Research) data from 2013, 24.3% of Indonesians were active smokers, with the daily average number of cigarettes smoked being 12.3.[5]

In fact, there are many toxic materials contained in tobacco or produced through smoking which lead to specific diseases.[6] For instance, smoking can increase the risk of dental caries.[3] Therefore, dental restoration, predominantly using composite resin, is required. According to research

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conducted by Mathias et al., when composite resin is exposed to cigarette smoke there will be an increase in water absorption.[3] Although the strongest effect in the oral cavity still remains unclear, high temperature (55° C) can increase kinetic water diffusion, water absorption, and resin solubility.[4]

Kretek cigarettes constitute a typical Indonesian tobacco product dominating 90% of the domestic cigarette market.[7] According to the Top Brand Award Index, the most famous non-filter kretek cigarette between 2012 and 2014 was Dji Sam Soe. In contrast to white cigarettes, kretek cigarettes use heavy tobacco derived from chopped tobacco mixed with cloves.[8] Consequently, when ignited they release a high concentration of eugenol derived from cloves, approximately 28,700–30,200 µg per cigarette (Dji Sam Soe brand).[7]

The processes of water absorption and eugenol release can then be used as plasticizers of the composite matrix, causing swelling which alters the dimensions of the restorative material.[9] Water absorption may be affected by the concentration of filler and rate of polymerization, as well as the type and number of monomers. Water absorption may subsequently result in the release of unreacted monomers, as well as the process of hydrolysis so that the chemical bond between the filler and the resin matrix is broken. In addition, polymer degradation can occur due to sudden temperature changes, resulting in damage to the silane coating resulting in the bond between the filler and the resin matrix being compromised. Degradation of the matrix and the release of filler particles onto the outer surface of the composite can lead to an increase in its surface roughness.[10,11]

The increased surface roughness of the restorative material can, in turn, trigger plaque and biofilm formation, thus increasing the risk of caries and periodontal inflammation. Surface roughness can also affect aesthetics, i.e. reducing the brightness of restoration, increasing susceptibility to discoloration and shortening the age of restoration.[12,13] As a result, this research aimed to evaluate the surface roughness of nanofilled and nanohybrid composite resins exposed to kretek cigarette smoke.

MATERIALS AND METHODS

This research represented a laboratory experimental study with post test-only control group design. The research samples constituted 12 nanofilled composite resins (Filtek Z350 XT) and 12 nanohybrid composite resins (Filtek Z250 XT) cylindrical in shape, 5 mm in diameter and 2 mm in thickness. The samples were then divided into four groups (n=6), namely: a nanofilled control group, a nanohybrid control group, a nanofilled experimental group and a nanohybrid experimental group.

The preparation of each sample commenced with the manufacture of an insulin syringe mold 5 mm in diameter and 2 mm thick which was given a celluloid strip base and placed on a plate glass. The composite resin was

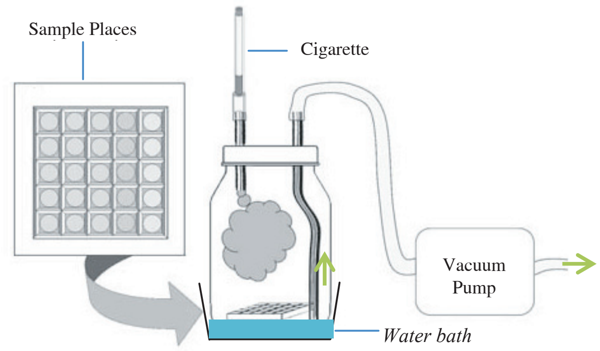

Figure 1. The smoking machine used in this research.[14]

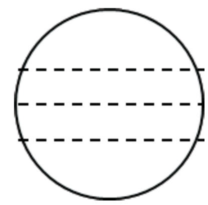

Figure 2. The pattern of sample measurement areas.[13]

subsequently inserted into the sample mold until it was full and then covered with a celluloid strip. A 1 kg glass plate was placed on top for 30 seconds in order to make the sample surface flat and solid.[13] The scales and glass plate were lifted and the composite irradiated with a light curing unit for 20 seconds at an intensity of 600–700 mW/cm^2 (as per factory rule: 400–1000 mW/cm^2) and a distance of 0.5–1 mm between the tip of the unit and the composite.[2] Hardened composite resin was subsequently removed from the mold.

Both of the composite control groups were immersed in distilled water and incubated at 37° C for 21 days. Meanwhile, both of the experimental groups were exposed to smoke derived from 12 cigarette bars placed in a smoking machine at an exposure temperature of 55° C inside the tube (using a water bath) as illustrated in Figure 1.[4] Smoke from each cigarette was introduced into the tube for 10 minutes[14] before being removed. After the exposure of the 12 cigarettes had been completed, the sample was immersed in distilled water and incubated at 37° C for ± 21 hours. Thereafter, both composite experimental groups were removed from the distilled water and dried using absorbant paper. All of the procedures described above were then repeated for 21 days. However, the distilled water had to be replaced daily for all groups.

After 21 days, the control and experimental group samples were removed from the distilled water and dried using absorbant paper. Both composite experimental groups were then immersed in acetone and agitated for ± 1 minute[15] in order to dissolve any cigarette tar attached to the sample surfaces.[16] Later, the surface roughness of each sample was measured using a Surface Roughness Tester (Mitutoyo SJ-201) tool with a standard stylus in three different areas (Figure 2), with the mean values being calculated.[13] The

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Table 1. The mean and standard deviation values of the surface roughness of nanofilled and nanohybrid composite resins.

Sample group	n	Mean (μm)	Standard Deviation
Nanofilled Control Group	6	0.16500	0.024763
Nanofilled Experimental Group	6	0.27433	0.036779
Nanohybrid Control Group	6	0.18000	0.032912
Nanohybrid Experimental Group	6	0.40183	0.054120

Table 2. The values of P in Independent T-test results relating to the surface roughness of composite resins

	Nanofilled control group	Nanohybrid experimental group
Nanohybrid control group	0.395**	0.000*
Nanofilled experimental group	0.000*	0.001*

Note:
* significant difference
** No significant difference

results of the composite surface roughness measurements were then statistically analyzed using an Independent-T Test with a confidence level of 95%.

RESULTS

In this research, four sample groups were analysed, namely: the nanofilled control group, the nanohybrid control group, the nanofilled experimental group exposed to kretek cigarette smoke and the nanohybrid experimental group exposed to kretek cigarette smoke. The research was conducted over 21 days, at the end of which period the surface roughness of each sample was measured using a Surface Roughness Tester (Mitutoyo SJ-201). The parameters used in this research consisted of a mean roughness value (R_a) with a micrometer unit (μm). The mean and standard deviation values of the surface roughness of the composite resins can be seen in Table 1. The results of the One Sample Kolmogorov Smirnov normality test confirmed the data to be normally distributed with a p value of >0.05, while those of the homogeneity test (a Levene's test) revealed it to be homogenous with a p value of >0.05.

In order to observe the significance of the differences between the research groups, an Independent-T test was subsequently, performed whose results confirmed important differences in the surface roughness of the composite resin between the nanofilled control group and the nanofilled experimental group, the nanohybrid control group and the nanohybrid experimental group, and the nanofilled experimental group and the nanohybrid experimental group ($p<0.05$). In contrast, there was no significant difference between the nanofilled control group and the nanohybrid control group ($p>0.05$) in terms of surface roughness.

DISCUSSION

This research was conducted to evaluate the effect of exposure to cigarette smoke on the surface roughness of nanofilled and nanohybrid composite resins. This research focused on kretek cigarettes since they are considered to be the most famous Indonesian tobacco product dominating 90% of the domestic cigarette market.[7] The investigation did not use artificial saliva, but distilled water, since the former has not been clinically proven to be a more relevant storage medium. In previous research focusing on the effect of storage media on composite resin micromorphology, the same results were obtained using distilled water and artificial saliva.[1] The samples of both experimental groups were soaked in acetone to dissolve the tar layer of cigarettes attached to the sample surfaces.[16] The administration of acetone to the surface of the nano composite for ± 1 minute, according to research conducted by Hamano et al., produced no effect on surface roughness since the nano composite resin has a strong crosslinking bond. Thus, it is unlikely that acetone can dissolve the composite surface.[15]

Moreover, the results of this research showed that there were significant differences in the surface roughness of the composite resins between the nanofilled control group and the nanofilled experimental group exposed to kretek cigarette smoke, as well as between the nanohybrid control group and the nanohybrid experimental group exposed to such smoke. This corresponds to the theory of composite degradation due to increased water absorption and acid exposure. The high temperature (approximately 55^o C) of cigarette smoke in the oral cavity can increase the kinetic energy of water diffusion so that water absorption into the composite resin increases.[4] Water absorption is also affected by filler concentration. Therefore, an increased amount of filler can decrease water absorption.[17] The composite resins used in this research were nanofilled composite with a filler concentration of 59.5% (Filtek Z350 XT) and nanohybrid composite (Filter Z250 XT) with a filler concentration of 68%. Consequently, the absorption of water in nanofilled composites is greater than that in in nanohybrid composites.

Water absorption can cause hydrolysis reaction, resulting in the water decomposing to H^+ and OH^-. Due to the presence of element O in the resin matrix, OH^- derived from the water is then absorbed into the matrix and attacks the siloxane bond (Si-O-Si), a bond linking the matrix and filler particles. Subsequently, this condition results in the breakdown of siloxane bonds to form silanol compounds,

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Si-OH and Si-O. In Si-O, disorientation of its electrons results in a reaction when its contact with water produces Si-OH and OH^-. The OH^- will subsequently break the siloxane bond again so that the reaction occurs continuously as long as the composite resin remains immersed in water. The longer these reactions occur, the greater the number of filler particles detached from the surface of the composite resin so that it becomes rougher.[18] This process occurs until the composite reaches saturation point.[19]

Furthermore, the burning of kretek cigarettes also releases a high concentration of eugenol derived from cloves, about 28,700–30,200 μg per cigarette compared to the average daily consumption of eugenol derived from food of about 70 μg.[7] Eugenol belongs to the phenol group and tends to be acidic. As a result, it can release H^+ ions from its hydroxyl groups which also contribute to the degradation of the composite resin because of a potential break in the siloxane bond.[18] Moreover, the free H^+ ion can react with the double bond carbon (C =) in the polymer chain of the resin matrix resulting in the polymer chain being disconnected which, in turn, triggers composite resin matrix degradation causing the filler particles on the surface to loosen easily. The release of the matrix and filler particles then results in many small cracks in the composite so that the surface roughness increases.[20]

In addition, cigarette smoke contains numerous other chemical components, as many as 4,800,[21] which may also affect the surface roughness of the composite resin. Within this research, the chemical component contained in kretek cigarette smoke with the highest concentration compared to others was found to be eugenol. There may also be other components working synergistically or in opposition to eugenol.

Based on research using scanning electron microscope (SEM) images, there are also matrixes and fillers found in the composite resin surface of the control group.[12] Nevertheless, the results of this research revealed that the surface roughness of the nanohybrid control group was slightly greater than the surface roughness of the nanofilled control group, but statistically not significantly different. This is due to the fact that the surface roughness of the composite resin can be affected by the size and volume of the filler.[22] Composites with larger filler particles have rougher surfaces than those with small fillers.[23] In nanofilled composites, all filler particles are round with a nano-size of 1–100 nm. Meanwhile, nanohybrid composites have irregular particle fillers with partial nano fillers (1-100 nm) and micro fillers (0.4–5 μm).[2,24] Therefore, nanohybrid control composites have a slightly larger surface roughness than composite nanofilled controls.

Furthermore, the results of this research also found that the surface roughness of the nanohybrid experimental group was significantly greater than that of the nanofilled experimental group. This is because filler particles of the nanohybrid composite (Ý5 μm) are larger in size than those of the nanofilled composite (Ý100 nm), resulting in increased surface roughness in the nanohybrid composite greater than that in the nanofilled composite.[23] Thus, the mean the surface roughness value of the nanohybrid experimental groups in this research was 0.402 μm, suggesting that the fillers released may be small or medium-sized, whereas the siloxane bond on the large filler particles may be only partially discontinued so that the filler particles are not released. However, this point requires further research.

In conclusion, kretek cigarette smoke can increase the surface roughness of nanohybrid composite resin to a greater extent than that of nanofilled composite resin. However, further research needs to focus on other chemical components that may affect composite surface roughness. In addition, such research is also expected to evaluate the surface roughness of composite resin with a confocal laser scanning microscopic (CLSM) tool in order to analyze the topography of surface roughness in detail.

REFERENCES

1. Erdemir U, Yildiz E, Eren MM, Ozel S. Surface hardness evaluation of different composite resin materials: influence of sports and energy drinks immersion after a short-term period. J Appl Oral Sci. 2013; 21(2): 124–31.
2. Sakaguchi R, Powers J. Craig's restorative dental materials. 13th ed. St. Louis: Mosby Elsevier; 2012. p. 143, 165–9, 179.
3. Mathias P, Santos SRB, Aguiar TR, Santos PRB, Cavalcanti AN. Cigarette smoke: effects on water sorption and solubility of restorative dental composites. Gen Dent. 2014; 62(2): 54–7.
4. Aguiar TR, Gaglianone LA, Mathias P. An overview of the impact of lifestyle behaviors on the operative dentistry. JBR J Interdiscip Med Dent Sci. 2014; 2(4): 1–6.
5. Infodatin Kemenkes RI. Perilaku merokok masyarakat Indonesia berdasarkan Riskesdas 2007 dan 2013: hari tanpa tembakau sedunia. Kementerian Kesehatan Republik Indonesia. 2015. p. 2–4.
6. Bertold CE dos S, Miranda D de A, Souza-Junior EJ, Aguiar FHB, Lima DANL, Ferreira RL, Claes IR, Lovadino JR. Surface hardness and color change of dental enamel exposed to cigarette smoke. Int J Dent Clin. 2011; 3(4): 1–4.
7. Polzin GM, Stanfill SB, Brown CR, Ashley DL, Watson CH. Determination of eugenol, anethole, and coumarin in the mainstream cigarette smoke of Indonesian clove cigarettes. Food Chem Toxicol. 2007; 45(10): 1948–53.
8. Jonatan S. Launching for marketer and entrepreneur. Jakarta: PT Gramedia Pustaka Utama; 2007. p. 173.
9. Darvell BW. Materials science for dentistry. 9th ed. Cambridge: Woodhead Publishing Limited; 2009. p. 218.
10. Tanthanuch S, Kukiattrakoon B, Siriporananon C, Ornprasert N, Mettasitthikorn W, Likhitpreeda S, Waewsanga S. The effect of different beverages on surface hardness of nanohybrid resin composite and giomer. J Conserv Dent. 2014; 17(3): 261–5.
11. Soetojo A. Penggunaan resin komposit dalam bidang konservasi gigi. Surabaya: Revka Petra Media; 2013. p. 1, 30, 34.
12. Hossam AE, Rafi AT, Ahmed AS, Sumanth PC. Surface topography of composite restorative materials following ultrasonic scaling and its Impact on bacterial plaque accumulation. An in-vitro SEM study. J Int Oral Health. 2013; 5(3): 13–9.
13. Oliveira ALBM de, Garcia PPNS, dos Santos PA, Campos JÁDB. Surface roughness and hardness of a composite resin: influence of finishing and polishing and immersion methods. Mater Res. 2010; 13(3): 409–15.

Dental Journal (Majalah Kedokteran Gigi) p-ISSN: 1978-3728; e-ISSN: 2442-9740. Accredited No. 32a/E/KPT/2017.
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DOI: 10.20473/j.djmkg.v51.i1.p37–41

14. Wasilewski M de SA, Takahashi MK, Kirsten GA, de Souza EM. Effect of cigarette smoke and whiskey on the color stability of dental composites. Am J Dent. 2010; 23(1): 4–8.
15. Hamano N, Chiang Y-C, Nyamaa I, Yamaguchi H, Ino S, Hickel R, Kunzelmann K-H. Effect of different surface treatments on the repair strength of a nanofilled resin-based composite. Dent Mater J. 2011; 30(4): 537–45.
16. Boyle P, Gray N, Henningfield J, Seffrin J, Zatonski W. Tobacco and public health: science and policy. Oxford: Oxford University Press; 2004. p. 53, 62.
17. Anusavice KJ, Shen C, Rawls HR. Phillips' science of dental materials. 12th ed. St. Louis: Elsevier Saunders; 2012. p. 278–87.
18. Aisya RKN. Pengaruh perendaman obat kumur mengandung eugenia caryophyllata oil terhadap kekerasan resin komposit tipe hibrid. Thesis. Jakarta: Universitas Indonesia; 2008. p. 8–9.
19. Noort R van. Introduction to dental materials. 2nd ed. London: Mosby Elsevier; 2002. p. 96–7, 109–13.
20. Maghfiroh H, Nugroho R, Probosari N. The effect of carbonated beverage to the discoloration of polished and unpolished nanohybrid composite resin. J Dentomaxillofacial Sci. 2016; 1: 16–9.
21. Tirtosastro S, Murdiyati AS. Kandungan kimia tembakau dan rokok. Buletin Tanaman Tembakau, Serat & Minyak Industri. 2010; 2: 33–44.
22. Alandia-Roman CC, Cruvinel DR, Sousa ABS, Pires-de-Souza FCP, Panzeri H. Effect of cigarette smoke on color stability and surface roughness of dental composites. J Dent. 2013; 41: e73–9.
23. Tantanuch S, Kukiattrakoon B, Peerasukprasert T, Chanmanee N, Chaisomboonphun P, Rodklai A. Surface roughness and erosion of nanohybrid and nanofilled resin composites after immersion in red and white wine. J Conserv Dent. 2016; 19: 51–5.
24. Moraes RR, Gonçalves LS, Lancellotti AC, Consani S, Correr-Sobrinho L, Sinhoreti MA. Nanohybrid resin composites: nanofiller loaded materials or traditional microhybrid resins? Oper Dent. 2009; 34(5): 551–7.

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