ResearchPaper: Effects of Three Whitening Toothpastes on the Surface Roughness and Morphology of a Nanohybrid Composite Resin

Fereshteh Naser Alavi[1*], Niloofar Moein[1], Mohammad Ali Yousefi[2]

[1] Assistant professor, Dental Sciences Research Center, Department of Operative Dentistry, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran
[2] Dentist, Rasht, Iran

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ABSTRACT

Introduction: The present in vitro study compared the effects of three whitening toothpastes on the surface roughness of a nanohybrid composite resin.

Materials and Methods: Fifty-five disk-shaped composite resin samples (Opallis) were produced and divided into five groups based on the brushing with toothpastes (n=11): 1. Whitening toothpaste containing blue-covarine (White Now, Signal); 2. Whitening toothpaste containing hydrogen peroxide (Optic White, Colgate); 3. Whitening toothpaste containing abrasive agents (Opalescence, Ultradent); 4. Conventional toothpaste (Max Fresh, Colgate); 5. Control (storage in distilled water). Brushing in all test groups was carried out using a brush testing machine. Changes in surface roughness (Ra) and the surface morphology of composite resin were evaluated using profilometry and electron microscopy, respectively. The data were analyzed with paired-samples t-test, Wilcoxon, Kruskal-Wallis, and Mann-Whitney tests. (α=0.05).

Results: Brushing with different kinds of toothpaste increased the Ra of the composite resin compared to the baseline ($p<0.05$). There were significant differences in Ra between the groups ($P<0.001$). The Optic White toothpaste group exhibited higher surface roughness than the conventional toothpaste group (Max Fresh) ($P<0.001$), with no significant differences from the White Now and Opalescence groups (P=0.065 and P=0.523, respectively).

Conclusion: Hydrogen peroxide-containing whitening toothpastes caused the greatest changes in surface roughness and morphology of the nanohybrid composite resin compared to the conventional toothpaste.

Keywords:
Composite resins
Tooth whitening agent
Toothpastes

**** Corresponding Authors:***
Fereshteh Naser Alavi.
Address: *Guilan University of Medical Sciences, School of dentistry, Lacan Road, Gas Square, Rasht, Iran*
Tel: *+981333486406*
E-mail: *minanasseralavi@yahoo.com*

1. Introduction

The microbial plaque on the tooth surfaces should be primarily removed mechanically using a powered or manual toothbrush and accessory interdental tools, including dental floss, toothpicks, or interdental brushes. Toothpastes have conventionally been used as a cleaning agent (1). Increased expectation concerning esthetic appearance at a community level has prompted manufacturers to produce novel whitening toothpastes.

Toothpastes have many ingredients in their formulation, with abrasive agents as the main ingredients responsible for removing stains (2). Their efficacy depends on the hardness, shape, size, distribution, and concentration of the particles and the applied force (3). Whitening toothpastes with a formulation containing hydrated silica, calcium carbonate, dihydrate phosphate dicalcium, calcium pyrophosphate, alumina, perlite, or sodium bicarbonate mechanically remove colored biofilms and chromophores from the enamel surface (4).

Whitening toothpastes containing oxidants (hydrogen peroxide) chemically modify the pigments adhering to the tooth surface, decreasing the severity of the discoloration (3,4). A novel whitening toothpaste contains blue covarine that brings about its whitening efficacy through a light effect instead of eliminating or changing pigments on the tooth surface, resulting in a color change in the tooth surface. This light effect occurs by placing a thin blue layer on the enamel surface. In addition, whitening toothpastes might contain silica particles that help remove stains from the external surface as an abrasive agent (5).

However, previous studies have shown that long-term brushing with whitening toothpastes can accelerate the destruction of the restoration surface, compromising the esthetic appearance (6). Composite resins are the most commonly used restorative materials in the oral cavity. An important consideration is the possibility of greater abrasion of the polymer matrix of these materials than the tooth structure. The smooth surface and luster of composite resin materials in the oral cavity might be affected by various factors over time, including temperature, oral cavity moisture (7), and oral hygiene measures. Several studies have evaluated the effects of brushing and toothpastes on the surface roughness of these materials (8). In this context, different toothpastes have different effects, depending on their formulation and ingredients (9).

The abrasion resistance of composite resins might differ depending on the shape and size of their filler particles (10). The surface topography of composite resins has an important role in biofilm aggregation. In addition to surface discoloration over time, increased surface roughness has a role in greater biofilm aggregation and increased incidence of periodontitis and recurrent caries at the tooth–restoration interface. In addition, increased surface roughness might increase the extent of abrasion over time through an increased coefficient of friction (11).

Considering the increased demand for and the use of whitening toothpastes and variations in their formulation, it is necessary to evaluate the possible effects of these toothpastes on the surface characteristics of composite resins. Therefore, the present study was undertaken to evaluate the effects of three whitening toothpastes (containing abrasive agents, hydrogen peroxide, or blue covarine) and a conventional one on the surface roughness and morphology of a nanohybrid composite resin. The null hypotheses was: there would be no significant difference between different toothpastes.

2. Materials and Methods

In the present in vitro study, 55 disk-shaped samples, measuring 5 mm in diameter and 2 mm in thickness, were prepared from the Opallis EA2 nanohybrid composite resin (FGM dental products Joinville, SC, Brazil). To this end, a plastic mold was placed on a glass slab and filled with composite resin. A transparent Mylar matrix was placed on it to prevent an oxygen-inhibited layer. Then the samples were light-cured through the Mylar band using an LED light-curing unit (LED.F, Woodpecker, China) for 30 seconds at a light intensity of 1100 mW/cm^2 with the light-conducting tip at proximity to the surface (12). The light intensity of the light-curing unit was repeatedly checked using a radiometer (Woodpecker, Medical Instrument, China). The inclusion criteria consisted of the absence of cracks and defects in visual examination and visualization under a stereomicroscope (SMZ1500, Nikon, Tokyo, Japan). To distinguish the superior surface of the samples, their underlying surface was numbered. The samples were incubated in distilled water at 37ºC to complete the polymerization process. After 24 hours, the superior surface of the samples was polished with Sof-lex disks (3M ESPE, USA) under standard conditions from medium to fine to superfine disks. Each disk was used for 30 seconds. Finally, the samples were rinsed with the air and water syringe.

The samples were randomly assigned to five groups according to the toothpaste type used (n=11):

1. Whitening toothpaste containing blue covarine (White Now, Signal)

2. Whitening toothpaste containing hydrogen peroxide (Optic White, Colgate)

3. Whitening toothpaste containing abrasive agents (Opalescence, Ultradent)

4. Conventional toothpaste (Max Fresh, Colgate)

5. Control (storage in distilled water)

Table 1 presents the characteristics of the materials. In the present study. a 10,000-round toothbrushing cycle was applied using a brushing machine Spadak, Iran), corresponding to one year of toothbrushing (13). Each composite resin sample was separately mounted on the special plastic plate of the abrasion chamber, and each plate was mounted in the cylindrical abrasion chamber. The chamber was placed in the machine, and a toothbrush with soft bristles (Panberes, Iran), too, was fixed on the machine so that the toothbrush bristles contacted the upper surface of the sample during a complete brushing cycle. The samples were brushed with a frequency of 2 Hz and a force of 2 N in a back and forth motion using 10 mL of the 33% aqueous solution of each toothpaste (13). Finally, the samples were retrieved and rinsed with the air and water syringe for 10 seconds. A new mixture of toothpaste and a new toothbrush were used for each sample.

Table 1. The characteristics of materials used in the study

Product name	Manufacturer	Composition
Opallis Composite resin	FGM, Brazil	Bis-GMA, Bis-EMA and TEGDMA, bariumalominosilicat, silicondioxide.Filler size:40nm-3µm (average:0.5µm), Loading: 57%volume
White Now toothpaste	Signal, Germany	Water, sorbitol, hydrated silica, SLS, sodium fluoride (0.32%), sodium saccharin, trisodium phosphate, dipentene and blue covarine
Optic White toothpaste	Colgate, USA	sodium monofluorophosphate (0.76%), calcium pyrophosphate, propylene glycol, copolymer, glycerin, SLS, tetrasodium pyrophosphate silica, hydrogen peroxide, sodium saccharin, phosphoric acid, sucralose, butylated hydroxytoluene and water
Oplalescence toothpaste	Ultradent, USA	Glycerin, water, silica, sorbitol, xylitol, poloxamer, SLS, carbomer, Sodium benzoate, sodium hydroxide, Sucralose, Xanthan Gum
Max Fresh toothpaste	Colgate, USA	sodium fluoride, sorbitol, water, hydrated cilica, SLS, flavor, cellulose gum, tetrasodium pyrophosphate, cocamidopropyl betaine, sodium saccharin, methylcellulose

Bis-GMA: bisphenol A glycol dimethacrylate; TEGDMA: triethylen glycol dimethacrylate; Bis-EMA: bisphenol A ethoxylated dimethacrylate; SLS: Sodium lauryl sulfate

A profilometer (Hommel Tester T8000, Hammel worker, Germany) was used to evaluate changes in the surface roughness (Ra) of the samples before treatment (24 hours after curing and polishing) and at the end of brushing rounds in all the subgroups at a tracing length of 4 mm, a cutoff of 0.8 mm, and a stylus rate of 0.5 mm/s. The surface roughness (Ra) of each sample was measured in µm at three areas (at the center of the sample and two points 1 mm away from the center), and its mean was reported as the surface roughness of that sample.

At the end of the toothbrushing rounds, one sample from each group was randomly selected for surface morphology evaluation. Samples gold-coated, and evaluated with SEM at a magnification of ×500. The relevant micrographs were taken and surface quality of samples were reported.

Shapiro-Wilk test was used to evaluate the normal distribution of data and Levene's test was used to evaluate the equality of the variances. In cases where the variances were equal, paired samples t-test was used to evaluate changes in surface roughness; otherwise, Wilcoxon's signed-ranks and Kruskal-Wallis tests were used. Mann-Whitney test with Bonferroni correction was used for two-by-two comparisons. SPSS 28 was used for statistical analyses at a significance level of P<0.05

3. Results

Table 2 presents the means and standard deviations of Ra values of composite resin samples before and after treatment in each study group. Based on the results, in all groups, except for the control group, the means of surface roughness after brushing were significantly higher than before brushing (Table 2).

Table 2. The means±standard deviations of surface roughness (µm) of composite resin in different groups

Groups	Ra (before)	Ra (after)	P-value
White Now	0.16±0.01	0.27±0.01	0.003*a
Optic White	0.16±0.01	0.30±0.01	<0.001*b
Opalescence	0.17±0.01	0.28±0.01	<0.001*b
Max Fresh	0.17±0.01	0.26±0.01	0.003*a
Control	0.17±0.01	0.17±0.01	>0.999

*significant
a. Wilcoxon signed ranks test; b. Paired samples test.

A comparison of the surface roughness of the samples before treatment showed no significant differences between the groups (P=0.510). After treatment there were significant differences in Ra values between groups (P<0.001, Kruskal-Wallis test). Two-by-two comparisons of the groups showed significant differences between the control group and all the other groups (P<0.05), except for the Max Fresh Colgate group (P=0.531). There was a significant difference between the Max Fresh Colgate and Optic White Colgate groups (P<0.001). There were no significant differences between the other groups (Table 3).

Figure 1 shows the SEM images of the study groups. The smoothest surface was observed in the control group. Prominent changes in the surface morphology were observed in the Optic White toothpaste group. However, effects of the other toothpastes were not distinguishable. In addition, abrasive particles of the toothpastes were observed on all samples, except control group.

Table 3. Two by two comparison of groups after treatment with different toothpastes

Groups	Control	Max Fresh	Opalescence	Optic white	White now
White now	0.003*	0.945	>0.999	0.065	
Optic white	<0.001*	<0.001*	0.523		
Opalescence	<0.001*	0.142			
Max Fresh	0.945				

*Significant
Mann-whitney test with bonferroni correction

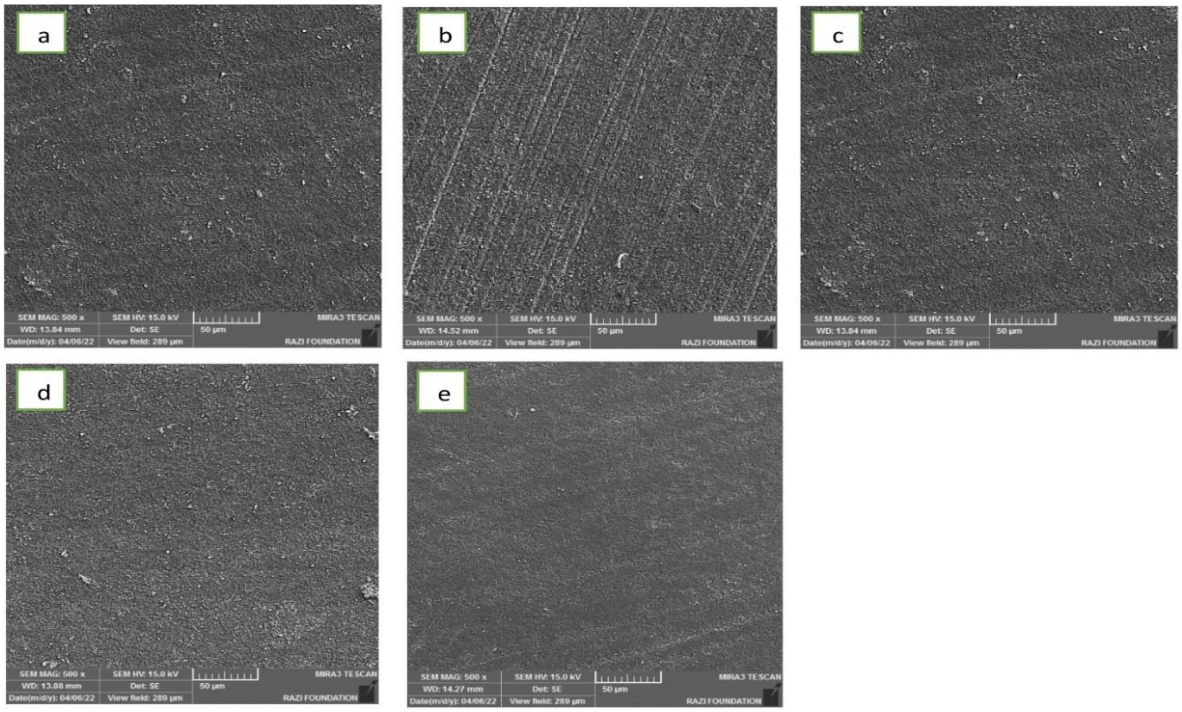

Figure 1. SEM images of composite resin after treatment (×500): (a) White Now, (b) Optic White, (c) Opalescence, (d) Max Fresh and (e) control

4. Discussion

The use of a toothbrush and toothpaste is the most common oral hygiene method; however, there is always the possibility of changes in the surface roughness of restorative materials under the effect of oral hygiene measures (14). Increased surface roughness increases bacterial adhesion and color changes in composite resin materials and decreases their luster. In this context, the material's characteristics and the materials used for oral hygiene are of almost importance (15,16).

The present study evaluated the effects of toothbrushing with three different types of whitening toothpastes and one conventional toothpaste on the surface roughness and morphology of a nanohybrid composite resin material. To this end, a simulator of the brushing procedure was used using a soft toothbrush with a 2-N force and 10,000 brushing cycles, equal to one year of toothbrushing (13). Toothbrushing is usually carried out manually, and toothbrushing force is different from one person to another. Based on ISO (International Standard Organization), force should be 0.5–2.5 N in toothbrushing tests (17). In producing composite resin samples, the polishing procedures were standardized to remove the resin rich surface layer. The similarity of the surface roughness of the samples was confirmed by measuring their surface roughness using a profilometer.

The results showed that toothbrushing with all the toothpastes tested in the study increased the surface roughness of composite resin samples compared to the baseline, consistent with some previous studies. Yilmaz et al (13) reported increased surface roughness of a nanohybrid composite resin after brushing with toothpaste. In a study by Roseline et al (18), too, toothbrushing with toothpaste increased the surface roughness of composite resins in 90 days.

An abrasive agent, such as silica and hydrated silica, is important in toothpastes because they have a role in removing dental plaque and extrinsic pigments (19). Therefore, considering the presence of abrasive agents in all toothpastes, toothbrushing with toothpastes increases the surface roughness of composite resins. Apart from the toothpaste ingredients, the toothbrushing process and the structure of composite resin affect their surface characteristics (20). In this context, in a study, toothbrushing with distilled water increased surface roughness, almost similar to toothbrushing with toothpaste (13). Concerning composite resin structure, Turssi et al reported that the behavior of hybrid composite reins was poor regarding wear, and these composite resins underwent more wear (10). Overall, composite resins with larger fillers have a higher surface roughness (21). However, other factors, too, might be involved, including filler shape, the distance between them, the composition of the organic matrix, and their chemical bond with the matrix. Furthermore, during toothbrushing, the soft polymer matrix is worn due to frictional forces, exposing the filler particles, which increases the surface roughness of composite resin (22).

In the present study, different whitening toothpastes were used, containing silica or hydrated silica as abrasive agents and chemical agents such as trisodium phosphate, calcium pyrophosphate, betaine, blue covarine, and hydrogen peroxide. The results showed greater surface roughness due to the effect of Colgate Optic White toothpaste than the Colgate Max Fresh conventional toothpaste. However, there were no significant differences between other bleaching toothpastes (Ultradent Opalescence and Signal White Now) and the Colgate Max Fresh conventional toothpaste groups.

Previous studies have shown that whitening toothpastes can induce surface changes in teeth and restorative materials (23). Roselino et al (18) reported that a whitening toothpaste (Colgate Luminous White) produced more surface roughness than a conventional toothpaste, which was attributed to the presence of abrasive particles with higher abrasive ability. However, Yilmaz et al (13) reported no significant differences in abrasion between Optic White and White Now whitening toothpastes and a conventional one. The discrepancies between different studies might be attributed to differences in composite resin structures, the toothpaste ingredients, study methods, and the interactions between these factors.

Concerning the abrasion by particles, Optic White and Opalescence toothpastes in the present study contained silica, while White Now and Max Fresh toothpastes contained hydrated silica. In this context, it has been shown that toothbrushing with toothpastes containing silica results in easier abrasion of the resin matrix, which creates more surface roughness; however, hydrated silica has a moderate level of abrasivity (6). The abrasivity of toothpastes is referred to as relative dentin abrasivity (RDA). Based on previous studies, the RDA of many toothpastes is within the safe limits (24,25); however, RDA is not the only factor involved in inducing surface changes (26).

Apart from the abrasive particles, the presence of hydrogen peroxide, too, might have affected the performance of Optic White toothpaste, facilitating its abrasivity. During the toothbrushing process, bleaching agents in the toothpaste might be absorbed by the resin matrix along with water, which is more noticeable in composite resins containing TEG-DMA matrix (such as Opallis) due to more water sorption (3). In addition, hydrogen peroxide can result in the separation of matrix polymer chains of composite resin by forming free radicals, weakening the surface characteristics of the material in the face of abrasion (27).

In general, the present study showed minimal difference in the surface roughness of composite resin samples with the use of whitening toothpastes (except for Optic White) and the conventional toothpaste. It seems that in the surface changes process of the material, toothbrushing with toothpaste was more important than the toothpaste type. In our study, SEM images confirmed the changes reported by the profilometer to some extent. Evaluation of these images showed that toothbrushing with toothpaste resulted in changes in the surface morphology compared to the control group. Greater changes and deeper and more noticeable lines were observed in the samples related to the Optic White toothpaste.

One of the limitations of the present study was a lack of adequate data on toothpastes, such as their abrasivity and the percentage of abrasive particles. In addition, the present study was carried out in vitro, without thermal and pH cycles of the oral cavity. Therefore, further studies are required under conditions close to the oral cavity with different toothpaste products and composite resins.

6. Conclusion

1. Toothbrushing with the whitening and conventional toothpastes increased the surface roughness of the nanohybrid composite resin.

2. Although the Optic White whitening toothpaste (containing hydrogen peroxide) was associated with greater surface roughness in composite resin samples, the changes induced by the White Now and Opalescence bleaching toothpastes were similar to those by the Max Fresh conventional toothpaste.

Ethical Considerations

Compliance with ethical guidelines

The study protocol was approved by the Ethics Committee of Guilan University of Medical Sciences. IR.GUMS.REC.1400.505

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None.

Authors’contributions

Fereshteh Naser Alavi: Conceptualization, Methodology, Writing - Review & Editing Niloofar Moein: Writing - Original Draft, Data Curation, Supervision Mohammad Ali Yousefi: Resources, Investigation, Visualization

Conflict of Interests

The authors declare no conflict of interest.

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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