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The effect of immersion in beverages and dental bleaching agents on the surface roughness of resin composites

Samra Korać[1]*, Irmina Tahmiščija[1], Lajla Hasić-Branković[1], Elmedin Bajrić[2], Aida Džanković[1], Alma Konjhodžić[1], Almira Softić[3]

[1]Department of Restorative Dentistry with Endodontics, Faculty of Dentistry with Clinics, University of Sarajevo, Bosnia and Herzegovina, [2]Department for Preventive Dentistry and Pedodontics, Faculty of Dentistry with Clinics, University of Sarajevo, Bosnia and Herzegovina, [3]Department for Mechanical Production Engineering, Mechanical Engineering Faculty, University of Sarajevo, Bosnia and Herzegovina

ABSTRACT

Introduction: Composite materials may be exposed to chemicals in food and beverages in the oral cavity, which can lead to changes in surface roughness. The aim of this *in vitro* study was to evaluate the surface roughness of two restorative materials after exposure to coffee and green tea followed by a dental bleaching procedure.

Methods: For nanofilled composite and microhybrid composite, 15 samples each were fabricated. Five specimens from each composite were stored in instant coffee and green tea for 4 h a day. After 30 days of immersion, specimens received dental at-home bleaching, using 16% carbamide peroxide (CP), for 7 h a day. The control group was stored in deionized water for 30 days. Surface roughness was determined by profilometry 24 h after polymerization, after 30 days of immersion, and after bleaching. The data were analyzed using a t-test for paired samples and mixed analysis of variance, at a 0.05 significance level.

Results: Neither beverages nor CP treatment significantly altered the surface roughness of the composites. There was no difference between the tested composite materials regarding roughness.

Conclusion: Surface roughness of the microhybrid and nanohybrid composites was not modified by coffee, green tea, and subsequent whitening treatment.

Keywords: Beverages; composite resins; profilometer; surface roughness; teeth whitening

INTRODUCTION

The success of dental composite restorations is largely determined by their surface properties. Surface roughness of dental composite materials relied on intrinsic and extrinsic factors (1). Exposure of composite materials to the complex oral environment can lead to surface degradation of the restoration due to chemical decomposition. Food, beverages, and oral care products may affect the mechanical, and optical properties of dental materials, including surface hardness, color, translucency, and surface roughness (2,3). The rough surface is more susceptible to staining in the oral cavity (4), and resulting in a negative effect on the aesthetic appearance of the restoration (5). Increased surface roughness is clinically relevant regardless of etiology, as it results in the accumulation of food debris and the formation of a biofilm, which consequently could cause secondary dental caries and periodontal tissue disease as well (6). The surface roughness of dental materials within the oral cavity must be 0.2 μm or less to reduce bacterial retention (7). In addition, the patient was not able to detect roughness values below 0.3 μm (8).

Natural teeth bleaching is an increasingly popular method and during this procedure, carbamide or hydrogen peroxide inevitably comes into contact with existing dental fillings. Peroxide-based products are effective in teeth whitening; however, their effect on the surface roughness of filling materials is controversial (6).

The most widely used composites are microhybrid composites and nanocomposites have been developed more recently (8). The nanosized filler in these materials fills spaces between larger particles, allowing them to provide a combination of the good mechanical or optical properties of macrofilled and microfilled composites, respectively (9).

To predict the behavior of materials in the oral environment, tests that mimic oral conditions are prevalent (2). This study aimed to evaluate the effects of staining beverages and bleaching on the surface roughness of microhybrid composite and nanocomposite.

*Corresponding author: Samra Korać, Department of Restorative Dentistry with Endodontics, Faculty of Dentistry with Clinics, University of Sarajevo, Bosnia and Herzegovina. E-mail: skorac@sf.unsa.ba

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The research hypotheses were that there would be differences in surface roughness after [1] immersion of the composites in coffee and tea [2] and subsequent at-home whitening treatment.

METHODS

Two light-polymerized composites (Table 1) were observed: a nanocomposite (Filtek Z550, 3M European Society for Paediatric Endocrinology [ESPE], St. Paul, MN, United States of America [USA]) and a microhybrid composite (Z250, 3M ESPE, St. Paul, MN, USA).

Fifteen cylindrical samples of each resin composite were prepared using a metallic mold (2 × 10 mm). A microscope glass slide and transparent Mylar® strip were placed under the mold, and the material was packed and covered with another polyethylene terephthalate strip and the glass plate. The samples were light-cured using a wireless LED lamp (Elipar™ FreeLight 2 LED Curing Light, 3M ESPE, St. Paul, MN, USA) with light intensity >1000 mW/cm^2 for 20 s. Dry finishing and polishing of the specimens were accomplished sequentially, using fine (24 μm) and superfine-grit (8 μm) Sof-Lex polishing disks (3M, ESPE, St. Paul, MN, USA), a new for each specimen (Figure 1). The aluminum oxide polishing disks were inserted in a low-speed dental handpiece with air cooling (at 10.000 rpm), used with repetitive strokes, by applying light pressure on the specimen surface for 10 s per grit. All polishing disks were disposed of after each use. Following the preparation, to complete the polymerization process, the samples were stored in glass containers with distilled water, at 37°C, for 24 h. Prepared specimens were immersed in daily replaced beverages for 4 h/day, while the rest of the day, they were kept in deionized water at 37°C for 30 days. Tested subgroups for both composites were:

- Group A (control): The specimens (*n* = 5) were immersed in 50 mL of fresh deionized water at 37°C
- Group B: The specimens (*n* = 5) immersed in 50 mL of prepared instant coffee (Nestle, Hungaria, Kft. Szerenczi Gyara); The contents (17.5 g) of a Nescafe instant coffee bag (three in one Classic) were poured with 150 mL of boiling water; the solution was stirred and cooled for 10 min (5).
- Group C: The specimens (*n* = 5) were immersed in 50 mL of green tea (Lipton green tea Nature Unilever, Belgium). A ready-made tea bag (30 g) was immersed in 200 mL of boiling water. After stirring for 10 min, the bag was removed.

The staining procedure was followed with the application of 16% carbamide peroxide (CP) whitening gel Vivastyle® (Vivadent, Schaan, Liechtenstein) to the entire surface of the specimens over a 14-day test period for 7 h/day, mimicking at-home application, at 37°C. Afterwards, bleaching gel was removed using cotton gauze, lightly washed with tap water for 1 min, and rinsed with deionized water. All specimens were returned to fresh deionized water at 37°C for the rest of the day.

The pH value of used materials was measured using a calibrated pH-meter PHYWE 13702.93 (Gottingen, Germany). The determined pH values for beverages were 6.45, 6.48, and 7.00, for Nescafe 3 in 1 Classic (Nestle), Lipton green tea Nature, and 16% CP, respectively.

All specimens were subjected to surface roughness testing using a contact profilometry Surftest SJ-210-Series 178-Portable Surface Roughness Tester (Mitutoyo). The profilometer was equipped with a diamond-tip stylus with a radius of 5 μm (Figure 2). The stylus head moved across the specimen, with a reference sampling length of 0.8 mm and a constant measuring speed of 0.75 mm/s. The applied measuring force was 4 mN. By definition, the mean values of surface roughness (Ra) were presented as the arithmetic means of the absolute deviation from the mean height of the surface. Contact-type surface roughness measurements of the specimens were performed 3 times, in different evaluation periods as follows: 24 h after polymerization, after 30 days of immersion in beverages, and after bleaching.

Statistical analysis was performed with Statistical Package for the Social Sciences for Windows v.20. The values of *Ra*

FIGURE 1. Polishing of the specimens.

TABLE 1. Materials used in this study

Product and manufacturer	Type (shade)	Organic matrix	Fillers			Filler load (wt-vl) %	LOT
			Composition	Average particle size (μm)	Average clusters size (μm)		
Filtek Z250 3M ESPE, St. Paul, MN	Microhybrid resin composite (A2)	Bis-GMA, Bis-EMA, UDMA, TEGDMA	Zirconium/silica particles	0.6	-	82–78	N535897
Filtek Z550 3M ESPE, St.Paul, MN	Nanohybrid resin composite (A2)	Bis-GMA, UDMA, Bis-EMA, TEGMA, PEGDMA	Surface-modified zirconium/*silica* clusters and non-agglomerated/ non-aggregated surface-modified silica particles	0.02	≤3	82–68	N502352

Bis-GMA-Bisphenol-A-glycidyl-methacrylate, UDMA-Urethane dimethacrylate, TEGDMA: Triethylene glycol dimethacrylate, Bis-EMA: Ethoxylated bisphenol-A-dimethacrylate, PEGDMA: Polyethylene glycol dimethacrylate were presented descriptively by their mean and standard deviation values. Data were analyzed using the following parametric tests: *t*-tests for paired samples and the mixed between-within-subjects analysis of variance (ANOVA) test for comparing between and within two tested composites during periods, with corresponding *post hoc* tests. The level of significance of $p < 0.05$ was adopted for all statistical analyses.

RESULTS

Means and standard deviations of surface roughness of the tested composites are shown descriptively in Table 2. The differences between mean values of universal composite samples immersed in water in the period between day 1 and day 30 from immersion were not found (paired-samples *t*-test: $t = 0.121$, $p = 0.905$). Similarly, differences between the mean values of nanocomposite samples immersed in water in the period between day 1 and day 30 from immersion were not found (paired samples *t*-test: $t = 1.500$, $p = 0.156$).

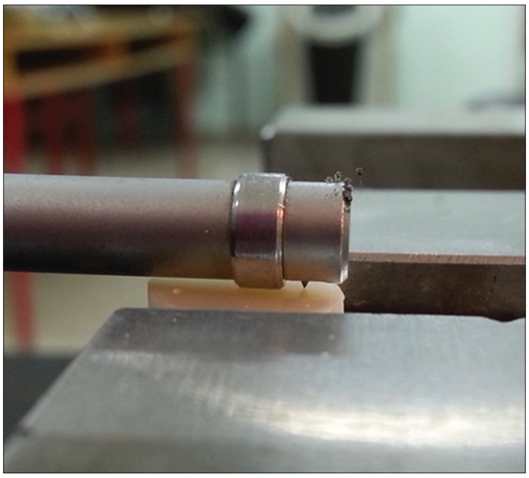

FIGURE 2. Surface roughness measurement with a contact stylus profilometer.

TABLE 2. Descriptive statistics of tested composites in different experimental conditions

Surface roughness (μm)	*n*	Mean	SD
Day 1			
Group A_microhybrid	15	0.1653	0.10049
Group B_microhybrid	15	0.1913	0.09970
Group C_microhybrid	15	0.2660	0.12922
Group A_nanocomposite	15	0.1913	0.06022
Group B_nanocomposite	15	0.2273	0.14320
Group C_nanocomposite	15	0.2587	0.14706
Day 30			
Group A_microhybrid	15	0.1627	0.07025
Group B_microhybrid	15	0.2493	0.12355
Group C_microhybrid	15	0.1967	0.09163
Group A_nanocomposite	15	0.1547	0.04596
Group B_nanocomposite	15	0.1920	0.11755
Group C_nanocomposite	15	0.2640	0.14545
Bleaching			
Group B_microhybrid	15	0.2167	0.09116
Group C_microhybrid	15	0.1940	0.06057
Group B_nanocomposite	15	0.2360	0.13902
Group C_nanocomposite	15	0.1867	0.08355

The results of the mixed between-subjects ANOVA test also showed that there were no statistically significant differences between the control samples of the microhybrid composite and nanocomposite, both over time ($F = 0.588$, $p = 0.450$; $F = 3.409$, $p = 0.54$; respectively) and according to the material ($F = 0.141$, $p = 0.710$; $F = 0.443$, $p = 0.511$; respectively).

Bleaching procedures with 16% CP did not cause statistically significant differences in surface roughness compared to basic values for microhybrid and nanocomposites (paired samples *t*-test: $t = -0.872$, $p = 0.398$; $t = 2.148$, $p = 0.05$; $t = -0.259$, $p = 0.800$; $t = 1.571$, $p = 0.139$; respectively). Furthermore, surface roughness was not statistically different between two tested composite materials, previously stained with instant coffee and green tea, after bleaching with 16% CP (paired samples *t*-test: $t = 0.742$, $p = 0.470$; $t = 0.081$, $p = 0.936$; $t = -1.974$, $p = 0.068$; $t = 1.826$, $p = 0.089$; respectively).

DISCUSSION

The final surface treatment of the composite specimens was performed as routinely required in clinical settings. The finishing and polishing methods considerably affect the aesthetic appearance and the durability of resin composite restoration (1). Pre-roughening of the specimens was performed sequentially from fine to superfine using abrasive paper Sof-Lex disks, as in previous studies (8,10,11). Flexible aluminum oxide disks proved to be successful in creating a smooth surface of the composite (1). This multiple-step system was found as the most effective polishing method compared to other systems (10,12).

In the present study, the restorative materials evaluated consisted of small filler particles, though, with the difference in average particle size (Table 1). If the surface roughness was higher than 0.2 μm, the accumulation of plaque was raised, and consequently, the possibility of secondary caries and the occurrence of periodontal disease was increased (6). It was claimed that spherically shaped nano-filler particles gave better polishability to the composite (13). However, the means and standard deviations of the initial roughness values of the two tested composites at baseline gained optimal results of the Ra threshold, indicated no differences between the products. Gonçalves et al. reported statistically similar the mean values of surface roughness after the treatment with Sof-Lex disks for the nanofilled and microhybrid composite resins (14). Furthermore, the previous study found no evidence showing that resin composite types can influence polishing results (15).

Intermittent immersion in beverages was applied according to the previous studies to accelerate the effect of beverages, simulating about 6 months of clinical exposure. Namely, 24 h immersion in liquids corresponds to about 1 month *in vivo* (16).

A rough surface negatively affects the appearance of composite restoration (3). Unaltered roughness after the action of the beverage indicates an improved aesthetic appearance, and reduced plaque deposition on the restoration (8). Concerning surface roughness, no significant differences were found after immersion, in agreement with several previous studies (11,17). Reddy et al. found a significant increase in the roughness of three types of composites after immersion in beverages (18). Tavangar et al. (10), Karatas et al. (8) and Reddy et al. (18) presented diverse material-dependent results. Differences in these results attributed to the chemical composition of the restorative materials, low pH value of the solution, and polishing technique (8,10,11,17,18).

The surface roughness of the composite was dictated by the content and distribution of fillers (8), the size, shape, amount of filler particles (10), and the interface between the filler particles and the resin matrix (2). The materials assessed in our study had a high percentage of filler loading in their composition (78% vol), which may be one of the reasons for the insignificant change in roughness. Increased filler loads lead to decreased molecular mobility (13). Nanocomposites, a more recent type of dental resins which contain proprietary nanoparticles and nanoclusters, showed the same pattern as the microhybrid composite Z250, the material they were derived from.

The composition of the matrix and degree of polymerization had a direct impact on surface roughness (8). It has been suggested that the possible change in roughness in the aquatic environment was due to the action of water, which reduced the mechanical properties of the polymer matrix (18). Water sorption led to matrix swelling, the occurrence of stress, and the consequent debonding of filler particles that fall out, resulting in the roughness increase (19). Acidic liquids provoke erosive effects (8). In this study, samples were intermittently immersed in beverages, and in the periods between immersions were kept in deionized water with almost neutral pH. Even though coffee and tea were slightly acidic drinks, they showed no erosion effects on the surface of dental composites. The water acted as a poor solvent for dental resin composites through a slow water sorption process (10). Therefore, continuous immersion and a longer period of immersion could lead to erosion of the material surface and a significant change in material roughness. Considering the results that immersion in instant coffee and green tea caused no significant difference in the roughness of the tested composites, the first hypotheses of the authors should be rejected.

Measurements of the composite surface roughness in this study were performed by profilometry, as in the previous studies (8,11,18). Profilometry provided two-dimensional information about an area based on the average value calculated from three measuring positions performed at cross directions, and repeated measurements can be obtained. However, the measurements covered a limited area of the sample, and the results could be different in another part of the specimen. Different results could be achieved by another method of analysis, as a previous research has shown inconsistent composite roughness results using atomic force microscope and profilometry (8).

For the second research question, it was found that bleaching with 16% CP for 7 h/day after immersion in green tea and coffee (Table 2) revealed no statistically significant difference in surface roughness compared to basic values for both tested composites or between the microhybrid composite and nanocomposite. Thus, for an optimal final restoration after whitening with 16% CP, it was not necessary to polish the composite material again.

It was known that the hydrolysis of dimethacrylate-based resins was a relatively slow reaction at neutral pH (5). It could be assumed that the Vivastyle 16% gel did not induce erosion of the composite surface and changes in surface roughness due to its neutral pH value (pH = 7) and low concentration of hydrogen peroxide. The previous study showed that Vivastyle was the least aggressive among tested whitening preparations (20). Furthermore, the high quantity of filler in the tested materials and a consequently small percentage of organic content made the composites less prone to the erosive action of bleaching agents.

The previous studies also showed no significant difference in composite surface roughness after bleaching using the at-home technique (6,21). In contrast to the present study, Dogan et al. (22), reported significant decrease in the surface roughness of composites bleached with 16% CP, while Kim et al. (23) showed a minor surface roughness change. However, others have demonstrated that application of relatively low concentrations of bleaching agents significantly increased roughness of the resin composite (24-26). These contradictory responses could be explained by the difference in protocols in terms of the exposure time, the difference in pH values, and the chemical composition of the gels used. Dogan et al. speculated that carbopol (carboxy polymethylene polymer) additive content was one of the major differences among bleaching products, and enhanced the loss of more inorganic fillers (22). The different results in the surface roughness of the resin composites might be related to the compositional differences of the products, especially monomers. Wang et al. (27) showed that the surface roughness changes of resin composites after bleaching depend on the material and time. Free radicals in the bleaching gel affect the organic resin (26). However, the inorganic filler of resin composites provides resistance to bleaching (27).

The present study has certain limitations; namely, restorative materials in the mouth are simultaneously exposed to the combined effect of different environmental factors. Furthermore, the specimens of the control group were immersed in deionized water. In the further study, artificial saliva would be used and could assess the long-term effects of immersion in different beverages on the surface roughness of several composites. The contact profilometer serves as a standard method for the flat surface profile detection using a direct contact of the stylus with the specimen. In further research, the measurements should be modified to observe the three-dimensional morphology of the composite surface and visualize the surface topography. Surface topography of restorative materials assessment could be estimated with scanning electron microscopy or atomic force microscopy to support the profilometric findings, provide both qualitative and quantitative data of surface roughness, and obtain comprehensive results.

CONCLUSIONS

According to the methodology used and based on the results of this research, the following could be concluded:

1. There was no significant change in roughness on the two tested dental composites by the action of coffee and tea

2. None of the tested materials demonstrated significant differences in the surface roughness values after application of 16% CP gel
3. When it comes to changing the surface roughness, the nanocomposite material did not prove superior to the microhybrid composite.

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CONFLICT OF INTEREST STATEMENT

The authors have declared no conflicting of interests.

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