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ORIGINAL ARTICLE

Effect of Brushing Time with a Whitening Dentifrice on Surface Roughness of Anterior Composite Resins

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ABSTRACT

Objectives: This study aimed to compare the surface roughness of three anterior composite resins with different filler size, rate, and shape after brushing for 5000, 10000, and 20000 cycles with a whitening dentifrice. **Methods:** 44 disk-shaped specimens of each material (5mm diameter, 2mm depth) G-aenial Anterior, Harmonize, Asteria were prepared and divided into four groups according to the brushing cycles (Initial, 5000, 10000, and 20000 cycles). Initial surface roughness values (Ra-values) were assessed using a profilometer and measurements were repeated after each brushing cycle. 4 specimens from each composite resin were observed by scanning electron microscopy before and after brushing. The data were analyzed by Shapiro Wilk., ANOVA, Tukey, Friedman, and Wilcoxon tests ($p<0.05$). **Results:** The Ra-values of all groups increased in proportion to the number of brushing cycles ($p<.05$). The Ra-values of both Asteria and Harmonize were significantly lower than the G-aenial after all brushing cycles ($p<0.05$). **Conclusion:** All of the materials demonstrated surface irregularities after 20.000 brushing cycles corresponding to 24 months. The degree of surface alteration increased with brushing time and depends on the composite's filler rate, size, and shape.

Key words: atomic force microscopy, composite, giomer, glass ionomer, microhardness, surface roughness

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INTRODUCTION

Composite resins are easy to manipulate and esthetically attractive restorative materials that are widely used by dentists.[1] The improvement of these materials is one of the most important advances in esthetic dentistry.[2] They consist of an organic matrix containing methacrylate monomers, inorganic filler particles, silanes, and photoinitiators.[3] The mechanical and esthetic properties of composite resins are determined by these components, therefore the development of these materials has focused on filler technology to increase the ratio of filler particles. Composite resins are classified as microhybrid, nanohybrid, microfilled, and nanofilled according to filler particles.[4]

The surface roughness of composite resins is a critical factor for the clinical success of a restoration. Changes in surface roughness may affect the longevity and esthetic properties of restorations.[5] Rough surfaces increase degradation in restoration surfaces and discoloration of restorations. However, many factors may affect the surface degradation of restorations. Brushing with a whitening dentifrice is one of the abrasive factors for esthetic restorations.[6,7] The use of dentifrices is essential for daily oral health care of individuals to achieve effective oral hygiene. In the past years, some components with whitening properties were added to the dentifrices, which have been used in the market for caries prevention and periodontal diseases. Regarding cosmetic features, these dentifrices gain property to prevent or remove stains on the tooth surface by the abrasives they contain, consequently whitening the teeth.[8] However, dentifrices with a high amount of abrasive contents may have a negative effect on the surface roughness of restorations.[9] The increase in roughness of composite resins may decrease gloss, which may affect the esthetic of composite restorations.[10] There are many studies on the effect of whitening dentifrices on the surface roughness of composite resins.[2,6,8] However, very few of them examine the variation in brushing time of composite materials with different filler ratios and shape.[6,11]

The purpose of this in vitro study was to compare the surface roughness of three esthetic anterior composite resins which have different filler size, shape, and rate by brushing with a whitening dentifrice on different timelines. The null hypothesis to be tested was that regardless of filler content, there would be no difference in the surface roughness of composite resins after 6, 12, and 24 months of brushing with a whitening dentifrice.

METHODS

Specimen preparation

A whitening dentifrice and three commercial esthetic composite resins were used in this study; their manufacturers, shades, contents, filler sizes, and filler rates are listed in Table 1. Enamel shades of three composite resins (Asteria, Harmonize, G-aenial anterior) were chosen in accordance with the type and size of filler particles. 44 specimens for each composite resin (a total of 132) were prepared using a silicone mold with a 5 mm diameter and 2 mm depth. The mold was positioned on a Mylar strip (Hawe Stopstrip, Kerr, Germany) and a glass plate and then composite resins were applied. Another Mylar strip was placed on the top of the composite followed by another glass plate, and a finger pressure was applied for 20 seconds to extrude the excessive composite resin and obtain a smooth surface. Then the composite resins were cured with a light-emitting diode light unit (Elipar S10, 3M, USA) for 20 seconds at a distance of 1mm from the upper surface of the mold in accordance with the manufacturers' instructions.

In order to reduce variability, all prepared specimens were finished and polished by a single operator. The finishing and polishing of the cured specimens were completed with six brush strokes, in the same direction with the aid of a drawn arrow, using the multi-step OptiDisc system (Kerr Hawe SA, Switzerland). This system consists of an extra-coarse disk for contouring, coarse/medium for finishing, fine for polishing, and extra-fine for high gloss polishing, which was manufactured from a flexible polyester impregnated with aluminum oxide particles of different sizes to obtain a smooth surface. The disks were changed after each specimen preparation. The polished specimens were cleaned with distilled water in an ultrasonic cleaner for 10 minutes to remove the remaining debris. All specimens were stored in distilled water for 24 hours at 37^0C before roughness evaluation.

Surface roughness evaluation and brushing simulation

The specimens were embedded into silicone molds prepared for the test machine in an acrylic resin. The initial surface roughness evaluation was performed 3 times on each specimen at different sites by a profilometer (Surftest SJ 201, Mitutoyo Co, Kawasaki, Japan) and the average of the values was calculated.

The acrylic tank of the brushing machine (MF-100 Toothbrush Machine, Esetron Smart Robotechnologies, Ankara, Turkey) was filled with a mixture of dentifrice and distilled water at a ratio of 1:3 by weight. Soft bristle toothbrushes (Oral-B Pro-Expert Sensitive, P&G, Eczacıbaşı, Kocaeli, Turkey) were used, with a load of 200 g. The brushing speed was 250 cycles per minute, carried out 5000 (5k), 10000 (10k), and 20000 (20k) cycles, cumulatively to imitate approximately 6 months, 12 months, and 24 months of brushing in clinical conditions, respectively. The toothbrushes and dentifrice mixture were changed after every cycle. The samples were ultrasonically cleaned in distilled water for 10 minutes, then dried by compressed air after every brushing cycle. The evaluation of the surface roughness values of the materials was performed after each cycle.

Scanning electron microscope (SEM) observation

Four specimens were selected from each group for SEM analysis, including uncycled, 5k, 10k, and 20k brushing cycles. The specimens were dried in a dehumidifier with silica gel for 72 hours, metalized with gold, and observed with a scanning electron microscopy (Quanta™ 450 FEG, FEI, Oregon, USA) under ×5000 magnification for qualitative analysis of the surface.

Statistical analysis

SPSS 19.0 was used for statistical analysis. Shapiro Wilk test was used for the test of normality. ANOVA was applied to compare surface roughness among the groups and the Tukey test was used for posthoc comparison. Friedman and Wilcoxon tests were applied to compare percentage change at different time points within each group. All tests used a significant level of $p=0.05$.

RESULTS

The surface roughness results are shown in Table 2. Significant differences were found for the surface roughness before and after brushing abrasion in all cycles for all of the composite resins ($p<0.05$). Concerning surface roughness values before brushing abrasion, 5k, 10k, and 20k brushing cycles, the G-aenial showed the highest and Asteria showed the lowest mean values with a significant difference ($p<0.05$). The Asteria did not exhibit a significant difference compared to the Harmonize ($p>0.05$). On the other hand, the surface roughness values of both Asteria and Harmonize were significantly lower than the G-aenial before brushing cycles ($p<0.05$). The surface roughness of all composite resins showed a significant increase after all brushing cycles ($p<0.05$).

Table 1. The manufacturer, type,contents, and filler rates of materials

Composite and Shade	Manufacturer	Type	Organic Content	Inorganic Content	Filler Rate %wt, %vol
G-aenial anterior (SE)	GC Europe, Leuven, Belgium	Microfilled Hybrid Composite	UDMA, dimethacrylates	Prepolymerized fillers (16–17 µm; silica, strontium and lanthanoid fluoride), 850 nm silica glass, 16 nm fumed silica	%73, %63
Harmonize (A2)	Kerr, Orange, CA, USA	Nanohybrid Universal Composite	BisGMA, BisEMA, TEGDMA	Spherical silica and zirconia particles (5-400 nm)	%81, %64,5
Estelite Asteria (NE)	Tokuyama Dental, Tokyo, Japan	Supra-nano spherical Hybrid Composite	Bis-GMA,Bis-MPEPP,TEGDMA, UDMA	Supra-Nano Spherical Filler (200 nm SiO2-ZrO2), composite filler (include 200 nm spherical SiO2-ZrO2)	%82, %71
Dentifrice İpana 3d white luxe perfection	P&G, Eczacıbaşı, Kocaeli, Turkey	Glycerin, Hydrated Silica, Sodium Hexametaphosphate, Aqua, PEG-6, Aroma, Silica, Sodium Lauryl Sulfate, Cocomidopropyl, Betaine, Trisodium Phosphate, Mica, Chondrus Crispus Powder, Sodium Saccharin, PEG-20M, Sodium Fluoride (1100 ppm), Xanthan Gum, Sodium Chloride, CI 77891, Sucralose, Limonene, Sodium Benzoate, pH:7.05			

Table 2. Surface roughness evaluation [interquartile ranges] of tested materials (The superscript letters indicate statistically homogeneous subgroups within the columns)

Composites	Before brushing	After 5000 cycles brushing	After 10000 cycles brushing	After 20000 cycles brushing
G-aenial anterior	0.1058 [0.06-0.14]^{a}	0.2031 [0.16-0.25]^{c}	0.2525 [0.19-0.32]^{e}	0.5219 [0.41-0.66]^{g}
Harmonize	0.0705 [0.05- 0.12]^{b}	0.1177 [0.09-0.14]^{d}	0.1498 [0.12-0.18]^{f}	0.4249 [0.33-0.55]^{h}
Asteria	0.0813 [0.05-0.12]^{b}	0.1086 [0.08-0.16]^{d}	0.1292 [0.09-0.19]^{f}	0.3768 [0.31-0.41]^{h}

Table 3. Percentage rates of change in surface roughness (The superscript letters indicate statistically homogeneous subgroups within the columns)

Composites	Rate % (Before brushing-5000 cycle) x100	Rate % (Before brushing-10000 cycle) x100	Rate % (Before brushing-20000 cycle) x100
G-aenial anterior	% 97^{a}	% 144^{c}	% 408^{ef}
Harmonize	% 74^{a}	% 125^{c}	% 546^{f}
Asteria	% 37^{b}	% 63^{d}	% 390^{e}

Percentage rates of surface roughness changes are presented in Table 3. The percentage rates were significantly different for each composite resin ($p<0.05$). The highest percentage rate between initial – 5k brushing cycles and initial -10k brushing cycles were obtained for G-aenial. The Harmonize and Asteria composite resins' percentage values did not show any differences in terms of the number of cycles ($p>0.05$). The lowest percentage increase was recorded in Asteria between initial evaluation and 20k brushing cycles, also without demonstrating any difference from G-aenial ($p>0.05$).

The SEM images of each composite resin before and after 5k, 10k, and 20k brushing cycles are shown in Figure 1. SEM images revealed substantial surface

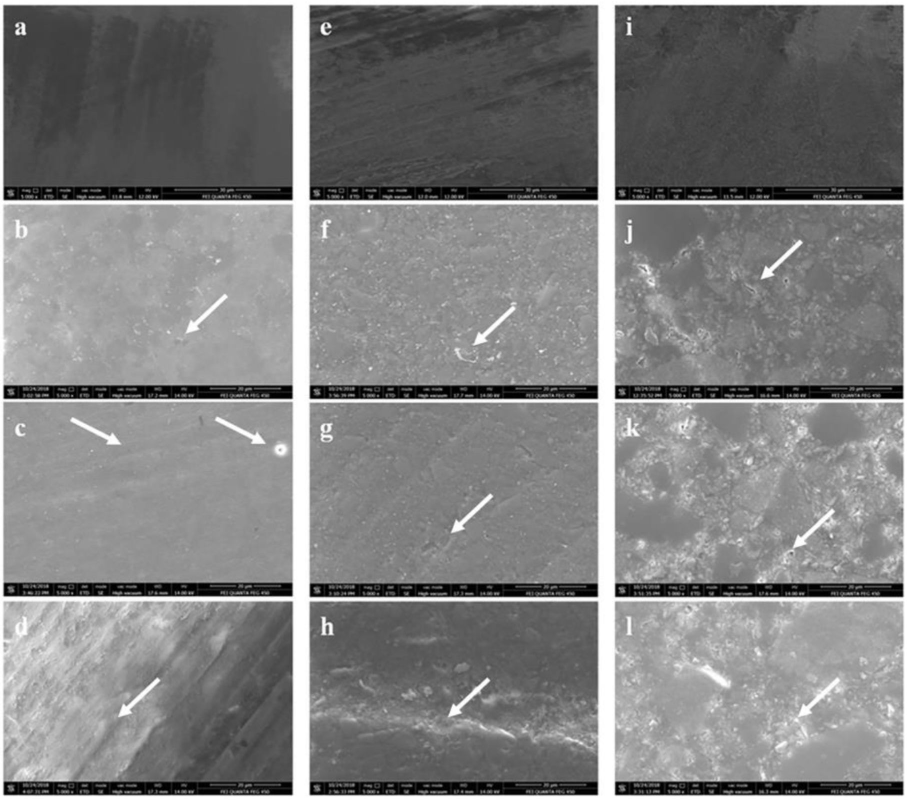

Figure 1. Scanning Electron Micrograph images (5000×) of specimens. (a) Asteria initial, (b) Asteria 5000 cycles, (c) Asteria 10000 cycles, (d) Asteria 20000 cycles, (e) Harmonize initial, (f) Harmonize 5000 cycles, (g) Harmonize 10000 cycles, (h) Harmonize 20000 cycles, (i) G-aenial initial, (j) G-aenial 5.000 cycles, (k) G-aenial 10000 cycles, (l) G-aenial 20000 cycles. (White arrows indicate the irregularities on the surface of composite resins)

smoothness for all materials before brushing cycles. However, all of the materials used in this study demonstrated surface irregularities and deteriorations after brushing cycles. Also, as the brushing time increased, more resin matrix removed, and more filler particles were exposed.

DISCUSSION

The centric and functional contacts, food abrasion, and interproximal contact areas may affect the clinic wear of a restoration. The abrasion that may occur as a result of brushing is commonly observed on the buccal surfaces and has been reported as a critical phenomenon in relation to composite resins' wear. The brushing action may abrade the surface of composite resin materials with a three-body abrasion process.[12] Recently, there is a wide variety of tooth cleaning materials available on the market, which addresses the problem of tooth discoloration. Various toothpaste components have been proposed to remove stains. Most of these products have special abrasive systems to remove stiffer stains, typically containing more abrasives and detergents than standard toothpastes.[13] Whitening dentifrices also contain additional chemical agents that help to remove external stains and improve abrasive cleaning.[14] The brushing with a whitening dentifrice may also increase the abrasive features. Therefore, this in vitro study evaluated the surface roughness of three novel and commonly used esthetic composite resins after simulating brushing abrasion with a whitening dentifrice.

Simulated brushing abrasion is considered as an established model and an important in-vitro wear factor in the literature that can reflect the clinical condition and cause the surface roughness of restorative resin materials.[11] Considering these factors, a brushing simulation was used to mimic the oral environment conditions in the present study. According to Sexson and Phillips[15], a patient performs approximately 15 cycles per brushing session. Therefore, 10k cycles are performed at the end of 1 year, maintaining oral hygiene due to twice a day brushing session habit. In this study materials' roughness values measured after 5k, 10k, and 20k cycles of brushing which are approximately equal to 6, 12, and 24 months of brushing.

The surface roughness can be analyzed in different techniques, however the most commonly used method in dentistry is the Ra-value. The Ra value is the arithmetic mean of separating profile fluctuations from an average line derived from the top and bottom of the fluctuations in tracking.[2] However, Stout[16] defined that the Ra-value is two-dimensional, it only provides information about the roughness height and gives no information about all of the surface profile. In order to support this information, a mean for creating an image of the surface is required. Therefore, obtaining SEM images may achieve qualitative value in three dimensions. The combination of qualitative data with a microscope and quantitative measurement ensure a precise characterization of the surface. Various studies have emphasized the importance of using more than one method to evaluate the surface characteristic.[2,6] Therefore, the SEM observations were used for the composite surfaces' qualitative analyses and profilometry for the quantitative analyses in the present study. Prior to the brushing simulation, the median roughness values of all composites were less than 0.1058, and surface irregularities were not observed under SEM magnification.

Composite resins that have larger filler particles would demonstrate a higher Ra-value after polishing. In addition, some researches have shown that materials with smaller particles have better gloss and lower roughness values after polishing.[17,18] In the current study, G-aenial yielded the significantly highest Ra-value which may be attributed to the material's largest fillers compared to the other two composite resins. On the other hand, Asteria yielded the lowest Ra-value and there was no significant difference between Asteria and Harmonize, which have smaller fillers than the G-aenial. The composite resin materials with small fillers that affect the initial Ra-value lead to improved finishing and polishing procedures.

After all cycles, Asteria and Harmonize composite materials demonstrated similar roughness values and these results were better than G-aenial composite. The average cluster size of supra-nano spherical hybrid composite is similar to that in nanohybrid universal composite fillers, smaller primary particles in these composites may wear by breaking off individual primary particles. Therefore, smaller defects may be observed on the surface and better gloss retention may be obtained.[19] The similar size concept of filler particles substantiates the less Ra- value of Asteria and Harmonize in the present study.

Among other factors, the surface roughness of the composite resins is directly related to the characteristics, amount, interparticle spacing, shape, and hardness of filler particles.[20] Thus, it was expected that the bigger filler particles (16-17 μm) in G-aenial would negatively affect it's Ra-value. These particles could reveal from the surface more through than those primary particles presented in Harmonize (5-400 nm) and Asteria (200 nm). They also form longer cantilevers, which will increase the angular moments that will facilitate the removal of these fillers from the material.[21] This appearance could achieve a higher roughness. These findings could be associated with this phenomenon.

In the present study, G-aenial showed the most surface abrasion of the filler particles, which may depend on having the lowest filler content according to SEM images; these findings are consistent with those of Draughn and Harrison[22], who state that higher Ra-value is associated with larger filler particles. G-aenial had more deep surface abrasion, but Asteria and Harmonize showed slight abrasion after 5k and 10k cycles. Asteria and Harmonize have smaller particles that are more homogeneous in size distribution that protect the resin matrix against abrasion and increase the durability of the composite resin.[17] These observations supported the findings of da Costa et al.[17] and Turssi et al.[18], who reported that composite resins which have smaller filler particles demonstrated a lower increase in Ra-value than the ones with larger filler particles.

Composite resins' surface degradation may be related to the weakening of matrix-filler bond, of fillers and the degradation of resin matrix.[23] The lowest percentage in increase of the roughness was found in Asteria after all cycles. Asteria has higher filler content (71% vol.) and lower resin matrix content compared to other composite resins. This nanofilled resin composite demonstrated acceptable results after all cycles. This finding may be related to a higher percentage of inorganic fillers of the material.

The filler content may affect the changes in roughness of composite resins. Melander et al.[24] found that composites containing spherical filler particles exhibited lower roughness values compared to composites with irregular fillers. Similarly, our results showed that Asteria and Harmonize exhibited better initial roughness values, and also following all cycles. Harmonize contains spherical silica and zirconia particles and Asteria contains supra-nano spherical filler.

A significant increase of Ra-value was detected in all the materials for all the cycles. Based on this finding, the null hypothesis was rejected. All composite resins' Ra values increased significantly after 5k, 10k, and 20k cycles of simulated brushing with a whitening dentifrice, and these results are accordance with other studies.[25-27] A clinical study by Bollen et al.[28] demonstrated that Ra of 0.2μm is the highest critical threshold for bacterial retention. Besides that, the Ra- value of 0.25-0.5μm could be detected by the patient's tongue.[29] Our results demonstrated higher Ra-values than 0.2μm after 5k cycles, and 0.25 after 10k cycles in the G-aenial, which may affect the bacterial retention and patient discomfort. After 20k cycles, all of the composite resins demonstrated higher than critical roughness values. Thus, an additional finishing and polishing procedures may be recommended for composite resins selected in this study for the patients using whitening dentifrice after 24 months.

CONCLUSION

Within the limitations of this in vitro study, all the materials revealed satisfactory surface characteristics before brushing simulation. For all the brushing cycles, supra-nano spherical hybrid composite resin demonstrated superior results compared to the microfilled hybrid composite resin. Anterior composite resins with a high filler ratio, small size, and spherical filler have been found to work better for a long-term whitening dentifrice use.

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