Original Article

# Surface Roughness of Different Composite Resins After Application of 15% Carbamide Peroxide and Brushing with Toothpaste: An In Vitro Study

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## Abstract

**Objectives:** This study aimed to evaluate the effect of toothbrushing after application of 15% carbamide peroxide (CP) on the surface roughness of three types of composite resins.

**Materials and Methods:** Twenty samples, measuring 4 mm in height and diameter, were fabricated of three composite resins namely microfilled (MF) Heliomolar HB, nanohybrid (NH) IPS Empress Direct and microhybrid (MH) Tetric Ceram HB. After polishing, the initial surface roughness was measured with a profilometer. The tray technique was used to apply 15% CP gel for 6 hours. Then, cleaning was carried out with an Oral-B electric toothbrush for 3 minutes in a tank containing a freshly mixed toothpaste. These procedures were repeated for 21 days. Then, the surface roughness was measured again and compared with the initial values. A mixed-design ANOVA model was used for the analysis of data ($P<0.05$).

**Results:** The baseline roughness was significantly lower in MF compared to the NH and MH composites ($P<0.001$). Roughness increased in all study groups during the intervention period; however, this increase was not significant in the MH group ($P=0.17$). Furthermore, the increase in roughness in MF was smaller than that in NH ($P<0.001$) and MH ($P=0.02$) groups.

**Conclusions:** The effect of intervention was more pronounced on NH and MH groups. Surface roughness changes were minor in MF composite resin.

**Key words:** Tooth Bleaching; Surface Properties; Composite Resins; Toothbrushing; Toothpastes

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## INTRODUCTION

Today, composite resins are among the most commonly used restorative materials. Different types of composite resins are available on the market which differ mainly on their filler technology. Among them, microfilled (MF), microhybrid (MH) and recently nanohybrid (NH) composite resins are extensively used in the clinical setting. The MF composite resins exhibit high polishability and high wear resistance in the clinical setting because they have very fine silica colloid particles instead of large fillers and yield smoother surfaces in the final restoration. However, they have lower physical and mechanical properties because of lower filler content and relatively high surface-to-volume ratio of microfine particles, compared to the hybrid types [1-3].

Attempts have been made to use a wider range of filler sizes to incorporate a higher percentage of fillers into the resin matrix of hybrid composite resins to enhance their mechanical and physical properties in addition to improve polishability. In MH composite resins, fine particles measuring 0.04 to 1 µm are mixed with microfine silicate particles measuring 0.04 to 0.2 µm. NH composite resins are produced by incorporating nanoparticles measuring 5 to 75 nm into MH composite resins [1-3].

At-home bleaching is an effective, simple and popular technique to enhance the esthetic appearance of the teeth [4, 5]. Carbamide peroxide (CP, 15%) which is recommended for at-home bleaching is predominantly used for 6 to 8 hours in a 24-hour period using a tray [6]. The bleaching agents exert different effects on the surface roughness and hardness of restorative materials especially composite resins, depending on the concentration and chemical composition of bleaching agents, treatment duration and type of restorative material [7-13]. Hajizadeh et al. [14] demonstrated that bleaching significantly increased the abrasion of composite resins, and NF composite resin was the most resistant to abrasion, while MH type was the least resistant. Furthermore, one typical pattern to maintain oral health during at-home bleaching procedure is to brush teeth with a toothpaste after removal of the bleaching tray [15]. Oral hygiene procedures and repeated use of home preventive measures (toothbrushing with toothpaste) might result in complications, including an increase in the surface roughness of dental materials and the tooth structure, resulting in enhanced bacterial accumulation and proliferation. The surface characteristics of dental materials affect plaque accumulation, abrasion and discoloration of restorations and finally their esthetic appearance [16-20].

The size and shape of fillers in the structure of composite resins might exert a great effect on surface roughness parameters [21]. According to Heintze and Forjanic [22], hybrid composite resins show the greatest increase in the mean roughness after simulated tooth brushing, while MF composite resins and compomers demonstrate the lowest increase in roughness. Wang et al. [23] showed that the effect of bleaching gels on surface roughness of composite resins is material-dependent and NF and MH composite resins are affected differently. Another study on the effect of 10% CP on the surface roughness and hardness of packable composite resins showed that surface roughness is affected by the bleaching agents but the surface hardness is not affected [13]. However, Zavanelli et al. [24] reported that 15% CP resulted in an increase in surface roughness of amalgam and glass-ionomer while 10% concentration of this material only increased the surface roughness of glass-ionomer, and the surface roughness of composite resins and ceramic was not affected.

Today, there is a trend toward widespread use of at-home bleaching technique with CP and composite resins for restoration of teeth because of the growing esthetic demands. Considering the fact that daily oral hygiene routines following the application of CP during the bleaching period may change the surface of restorative materials similar to changes reported on tooth surfaces [25, 26], this study aimed to investigate the effect of toothbrushing with toothpaste after bleaching with 15% CP on the surface roughness of MH, NH and MF composite resins.

## MATERIALS AND METHODS

For the purpose of this in vitro study, three different composite resins were selected: Heliomolar HB (Ivoclar Vivadent, Amherst, NY, USA) MF composite, IPS Empress Direct (Ivoclar Vivadent, Amherst, NY, USA) NH composite and Tetric Ceram HB (Ivoclar Vivadent, Amherst, NY, USA) MH composite. Table 1 presents the general characteristics of the composite resins used based on the information provided by the manufacturers.

A total of 20 samples were fabricated of each composite resin with the use of a plastic mold measuring 4 mm in diameter and height. The composite resins were packed in plastic molds and sandwiched between a matrix band and a glass slab using constant force and within the same period of time.

**Table 1.** General characteristics of the composite resins evaluated in this study

| Composite resin | Type | Composition | Filler Content | Filler size range in µm(mean size) |
|---|---|---|---|---|
| Heliomolar HB | Microfilled | Bis-GMA, urethane dimethacrylate, decanediol dimethacrylate, highly dispersed silicon dioxide, prepolymer, ytterbium trifluoride, stabilizers, catalysts and pigments | 66.7% (weight) 46% (volume) | 0.04-0.2 (0.1) |
| IPS Empress Direct | Nanohybrid | Bis-GMA, urethane dimethacrylate, ytterbium trifluoride, tricyclodecane dimethanol dimethacrylate, catalysts and stabilizers, pigments | 75–79% (weight) 52–59% (volume) | 0.04-3.0 (0.55) |
| Tetric Ceram HB | Microhybrid | Bis-GMA, triethylene glycol dimethacrylate, urethane dimethacrylate, barium glass filler, ytterbium trifluoride, highly dispersed silica, mixed oxide, catalysts and stabilizers, pigments | 81% (weight) 63% (volume) | 0.04-3.0 (0.7) |

Then, each sample was light-cured for 40 seconds from each side using Astralis 7 light-curing unit (FL-9494; Ivoclar Vivadent AG, Schaan, Liechtenstein) with a light intensity of 400 mW/cm$^2$. Then, the samples were immersed in distilled water at 37°C for 24 hours. Subsequently, the samples were mounted in cold-cure acrylic resin and their surface was polished using a composite resin finishing diamond bur (Teeskavan, Tehran, Iran). The surface of the samples was parallel to the horizon to ensure their correct placement in the profilometer. Then, polishing discs (Sof-Lex; 3M ESPE, St. Paul, MN, USA) along with 6 and 1 µm diamond abrasive paste (Microdont, Sao Paulo, Brazil) were used in association with water spray to provide a very smooth surface.

The baseline surface roughness of the samples was measured using a profilometer (Marsurf-PS1; Mahr, Göttingen, Germany) and defined as the mean of elevations and depressions measured on the surface of the material. During the test, a diamond rod, measuring 2 µm in diameter, randomly scanned the material surface at a definite distance (1.25 mm) at 3 points (once every 0.25 mm) with a constant speed of 0.1 mm/s using 0.7 mN force. The mean surface roughness was recorded using a numerical value as Ra.

Then, the samples underwent a bleaching procedure. First, a tray measuring 1 mm in thickness was fabricated for each sample using ethyl vinyl acetate plates with the use of a vacuum machine. Then, 0.02 mL of 15% CP gel (Opalescence F; Ultradent, UT, USA) was applied into the tray, and the tray was placed over each sample for 6 hours daily for a total period of 21 days. After completion of the daily bleaching procedure, the samples were rinsed with deionized distilled water for 5 seconds and were brushed using an electric toothbrush (Oral-B Vitality Precision Model; Oral-B Corp., OH, USA) in a tank containing a fresh mixture of toothpaste (Opalescence whitening toothpaste; Ultradent, UT, USA) with 1 part (50 g) of toothpaste and 3 parts of deionized distilled water (150 g). The toothbrush was fixed to a rod with the use of a holder and tooth brushing was carried out for 3 minutes using a typical force of 200 g. The amount of force applied was determined with the use of an orthodontic gauge. The toothbrush had multi-tufted nylon bristles. A new toothbrush head was used for each sample. The samples were immersed in the solution and the solution was completely agitated before use. The toothpaste mixture was refreshed every 3 days to preserve its neutral pH. Subsequent to daily tooth brushing, the samples were rinsed with distilled

**Table 2.** Inter- and Intra-group changes in the mean roughness value (standard error) in the study groups

| | Surface roughness | | |
|---|---|---|---|
| **Composite resin** | **Microfilled** | **Nanohybrid** | **Microhybrid** |
| Before intervention* | 0.18 $^{A}$ (0.02) | 0.28 $^{B}$ (0.01) | 0.28 $^{B}$ (0.02) |
| After intervention $^{¥}$ | 0.23 $^{a}$ (0.04) | 0.45 $^{b}$ (0.03) | 0.33 $^{b}$ (0.03) |
| P-value$^{♯}$ | 0.01 | 0.001 | 0.17 |

♯ P-values for intra-group comparisons
* Different uppercase letters mean statistically significant differences at baseline (P<0.05).
¥ Different lowercase letters mean statistically significant differences in roughness change after the intervention (P<0.05).



water and stored in artificial saliva at 37°C until the next day. The chemical composition of the artificial saliva consisted of the followings: 100 mM $CaCl_2$, 3.0 mM $KH_2PO_4$ and 100 mM NaCl (pH=6.30). A digital weighing machine was used to weigh the chemical agents. The afore-mentioned chemical agents were poured into a graduated glass container and mixed with 2 L of deionized distilled water. Then, the pH of the solution was adjusted with a pH meter using NaOH solution.

The bleaching and cleaning procedures were continued for 21 days in all the groups. Next, the surface roughness of the samples was measured again using the same profilometer.

Data were analyzed using SPSS version 16 (SPSS Inc., IL, USA). The Shapiro-Wilk and Levene's tests were used to assess the normality of data and homogeneity of variances, respectively. Log transformation was considered for the roughness data due to right skewness.

A mixed-design ANOVA model was used to assess the effect of intervention and to achieve the adjusted mean changes to assess the differences between the groups. To avoid violation of the assumption of sphericity, Greenhouse-Geisser correction was applied to correct the degrees of freedom. To evaluate the differences between groups with regard to baseline evaluations, pairwise comparisons based on time, which were corrected by Bonferroni adjustment, were performed in a mixed-design ANOVA model.

We used transformed variables to our statistical inferences, and presented main findings in terms of statistics which have been back-transformed to usual scale. P-value <0.05 was regarded as statistically significant.

## RESULTS

The mean surface roughness values and the related standard errors are presented in Table 2. At baseline, the amount of roughness was significantly lower in MF compared to NH (P<0.001) and MH (P<0.001) groups. Intra-group comparisons declared that the amount of roughness increased in all study groups over the intervention period; however, it was not statistically significant in MH (P=0.17) group. In MF group, the surface roughness increased from 0.18±0.02 to 0.23±0.04 (P=0.01) and in NH group, it increased from 0.28±0.01 to 0.45±0.03 (P=0.001).

The inter-group comparisons declared the significant effect of intervention on surface roughness, such that there was a smaller increase in roughness value in MF than in NH (P<0.001) and MH (P=0.02) groups. There was no significant difference between NH and MH groups (P>0.05).

## DISCUSSION

In the recent years, different types of composite resins with different compositions and mechanical properties have been marketed and can be used for reconstruction of the structure, shape, color and function of teeth in patients demanding esthetic treatments. Any change in the oral environment, including the use of bleaching procedures which are associated with daily oral hygiene practice, might result in adverse effects on these restorative materials. Degradation of the surface of composite resins might lead to abrasion, surface roughness and discoloration of restorations. An increase in the surface roughness may lead to gingivitis and periodontal problems through an increase in plaque accumulation [27-29].

In the present study, the effect of bleaching accompanied by oral hygiene routines was evaluated on the surface roughness of three different types of commonly used composite resins (MF, MH and NH). To simulate a bleaching procedure similar to the at-home bleaching technique, the samples were exposed to 15% CP gel for 6 hours daily for a total of 21 days, followed by toothbrushing with toothpaste in a similar manner for all the samples. The technical specifications of ISO in abrasion studies with the application of toothbrushing are limited to a force range of 50-250 g; in the present study, 200 g force was applied [17]. In order to simulate the oral clinical conditions as closely as possible, the samples were stored in artificial saliva.

Based on the results, daily toothbrushing after bleaching may significantly increase the surface roughness of composite resins. Similarly, Voltarelli et al. [30] showed that toothbrushing immediately after chemical degradation of the composite resin surface results in an increase in surface roughness in vitro. Immersion in chemical solutions gives rise to changes in the soft resin matrix, resulting in exposure of rough filler particles. These exposed filler particles are separated from the surface as a result of toothbrushing and the surface becomes rougher [30]. In some studies, scanning electron microscopic and profilometric analyses have shown that 10% to 16% CP gel (with 3.6% to 5.76% concentration of hydrogen peroxide) can result in a slight but significant increase in surface roughness and porosity of hybrid and MF composite resins [7, 12, 27]. The increase in surface porosity might be explained by the destructive effect of oxidative bleaching agents on the polymer matrix of resin materials [7, 27]. The inorganic filler particles are possibly inert even under very acidic conditions [31]. In addition, the negative effect of oxidative bleaching agents on the resin matrix through water sorption of the restorative material and relative or complete debonding of the fillers is still a matter of controversy; this factor might decrease the surface integrity and hardness of the material [27].

Furthermore, in the present study, NH and MH composite resins exhibited a greater increase in surface roughness compared to MF composite resin. This phenomenon was also observed by Voltarelli et al [30]. Generally, the surface roughness of each material is the cumulative effect of several factors, including the type, shape, size, hardness and the distribution of filler particles, the type of resin matrix, the ultimate limit of the material's conversion rate after polymerization, the quality of bond between the filler and the resin matrix and the stability of the silane coupling agent [18, 21, 22]. The surface roughness increases with an increase in the size of filler particles and their irregular shape vs. their sphericity. Monomodal composite resins (containing small spherical filler particles) have the smoothest surface while multimodal composite resins (containing filler particles with irregular shapes and different sizes) exhibit the roughest surface. Fillers with small sizes can attach to the resin matrix and yield a smoother surface [21]. The presence of small particles between larger fillers results in a reduction in inter-particle distance and the amount of resin matrix, improving the general properties of hybrid composite resins. Therefore, hybrid composite resins are expected to exhibit a greater increase in surface roughness compared to MF types. This was also confirmed by Heintze and Forjanic [22], who showed that after toothbrushing with a mixture of toothpaste and distilled water, hybrid composite resins exhibited the greatest increase in surface roughness, while MF composite resins exhibited the least increase. Some studies have failed to show any relationship between the filler size and surface roughness after toothbrushing. In this context, da Silva et al. [20] reported a significant increase in the surface roughness of MF, MH and nanofilled composite resins after 10 weeks of brushing; however, the differences between the three groups were not statistically significant. In the present study, the mean sizes of filler particles in the IPS Empress Direct, Tetric Ceram HB and Heliomolar HB composite resins were 0.55, 0.7 and 0.1 µm, respectively. The mean size of the particles by itself cannot predict the resistance of the material against tooth brushing [21]. In the majority of composite resins, the filler particles in the matrix do not exhibit normal distribution. As a result, the mean size of the particles does not provide valid data in relation to the amount of small, medium and large particles within the composite resin mass. However, it can affect the resin's resistance against abrasion as the result of attrition and brushing [22].

In addition to the filler particle characteristics, the type of the resin matrix in the structure of composite resins can also affect the results. According to Ryba et al, [32] UDMA and Bis-EMA with a high molecular weight form less durable bonds and therefore have a softer matrix. Based on the brochures of the materials evaluated in the present study, the matrix of IPS Empress Direct is composed of dimethacrylates only but the matrix of Heliomolar HB and Tetric Ceram HB is composed of Bis-GMA, UDMA and decanediol DMA.

Finally, it should be pointed out that the differences in the results of various studies might be explained by differences in the forces applied by the toothbrushes, the number of tooth brushing cycles, the hardness of toothbrush bristles, the differences in the chemical composition of toothpastes, differences in preparation of the samples and differences in the evaluation of the mean surface roughness. Today, in addition to the immense variety of composite resins available on the market in terms of composition and structure of the resin matrix and filler particles, various types of toothpastes with different combinations of bleaching agents and other therapeutic components are available, which complicate the generalizability of the results to the clinical setting. However, further studies can be useful in this regard.

## CONCLUSION

Under the limitations of the present in vitro study, the results showed that toothbrushing with toothpaste during the bleaching period with 15% CP resulted in an increase in surface roughness of composite resin restorations and this effect was more pronounced in NH and MH composite resins. There were minor changes in the surface roughness of MF composite resin.

## ACKNOWLEDGEMENT

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