SCANNING VOL. 38, 277–283 (2016)

The Effect of Home Bleaching Agents on the Surface Roughness of Five Different Composite Resins: A SEM Evaluation

Esra Cengiz,[1] Sevcan Kurtulmus-Yilmaz,[2] Nuran Ulusoy,[1] Sule Tugba Deniz,[3] and Ece Yuksel-Devrim[4]

[1]Faculty of Dentistry, Department of Restorative Dentistry, Near East University, Mersin, Turkey
[2]Faculty of Dentistry, Department of Prosthodontics, Near East University, Mersin, Turkey
[3]Faculty of Dentistry, Department of Prosthodontics, Biruni University, Istanbul, Turkey
[4]Private Practice, Istanbul, Turkey

Summary: The aim of this study was to investigate the effect of hydrogen peroxide (HP) and carbamide peroxide (CP) on the surface roughness of five different composite resins using profilometer and scanning electron microscope (SEM). Thirty-six specimens (1 mm thick, 10 mm in diameter) of five composite resins were fabricated. Each composite group was equally divided into three subgroups as control, CP and HP. In control group, specimens were stored in daily refreshed distilled water during the 14-day testing period. In other groups, 10% HP (Opalescence Tres-white) and 10% CP (Opalescence PF) were applied and surface roughness values (Ra) of each specimen were measured with a profilometer at the end of 14 days. Additionally, SEM analysis was performed to evaluate the surface deformations of composite resins. Data were analyzed with Kruskal–Wallis and Mann–Whitney U tests. Ra values of composite groups exposed to bleaching agents were statistically higher than control group ($p < 0.05$). There was no significant difference between Ra values after HP and CP application within each composite group while SEM micrographs showed higher surface alterations at HP group compared to CP. Among the composite resins tested, Ceram-X Mono revealed the lowest Ra values after CP and HP applications as seen at SEM images. Home bleaching agents increased the surface roughness of all composites. Except CP applied Ceram-X mono specimens, Ra values of all composite resins evaluated in this study exceeded the critical limit of 0.2 μm. Ceram-X mono was the least affected composite material after bleaching application. SCANNING 38:277–283, 2016. © 2016 Wiley Periodicals, Inc.

Key words: surface roughness, ormocer, hydrogen peroxide, carbamide peroxide, scanning electron microscope

Conflicts of interest: None.

Address for reprints: Esra Cengiz, Faculty of Dentistry, Department of Restorative Dentistry, Near East University, Lefkosa, Mersin 10, Turkey 99010
E-mail: dtesracengiz@yahoo.com

Received 2 December 2015; Accepted with revision 22 January 2016

DOI: 10.1002/sca.21307
Published online 8 February 2016 in Wiley Online Library (wileyonlinelibrary.com).

Introduction

Bleaching is one of the most commonly used clinical procedures to improve the esthetics of vital teeth. Vital-tooth bleaching can be performed in the office by the dentist using high concentrations (25–35%) of hydrogen peroxide (HP), or at home by the patient using lower concentrations (10–16%) of carbamide peroxide (CP) and HP (Haywood, '92; Minoux and Serfaty, 2008). CP solution is not stable and in contact with saliva or tissue, it immediately dissociates into and 7–10% urea and 3–5% HP which is considered as its active ingredient (Haywood, '92, '94). HP is further degraded into oxygen and water whereas urea breaks down into ammonia and carbon dioxide. HP shows its bleaching effect by acting as a strong oxidizing agent through the formation of free radicals, reactive oxygen molecules, and HP anions (Eimar *et al.*, 2012).

From the procedure standpoint, although bleaching is accepted as an efficient treatment and safe for soft tissues, it may not be safe for dental materials that have high erosive or degradation characteristics (Villalta *et al.*, 2006). Due to their organic matrix, composite resin materials are more prone to especially chemical alteration compared to other dental materials like inert metal or ceramic restorations (Davis, 2003; Hannig *et al.*, 2007). Micro-hybrid composite resins have been conventionally used for esthetic restorations however since the development of nano-composites, nano-hybrid composite resins have become most preferred composite resins due to the improved mechanical properties combined with better lasting polish retention and esthetics (Davis, 2003; Mitra *et al.*, 2003). Beside the inorganic content, monomers may also affect the mechanical and optical properties of the composite resins. A recently introduced material, ormocer differs from conventional composite resins in terms of monomers and inorganic molecules. Ormocer material consists of inorganic-organic network which is performed by polycondensation in addition to the silanated inorganic filler particles (Kalra *et al.*, 2012).

When composite resins are submitted to bleaching agents, this chemical reaction may alter the surface characteristics (Hafez *et al.*, 2010; Rattacaso *et al.*, 2011) by accelerating the hydrolytic degradation (Wang *et al.*, 2011) and inducing oxidative cleavage of polymer chains in resin matrix (Hannig *et al.*, 2007). The degree of alterations can vary according to the composition, exposure procedure of bleaching gel and the content of resin material. Therefore, due to the structural modifications, ormocer material is expected to show different resistance to the bleaching agents when compared to conventional composite resins.

The impact of bleaching agents on the surface roughness of composites resins have been tested in several studies (Hafez *et al.*, 2010; Rattacaso *et al.*, 2011; Wang *et al.*, 2011; Turker and Biskin, 2013) however, to the best of our knowledge, the available data on the effect of home bleaching treatment on surface roughness of ormocer based composite resin is limited.

The aim of this study was to investigate the effects of different home bleaching agents on three nano-hybrid, a micro-hybrid and an ormocer based composite resin by analyzing surface changes using profilometer and scanning electron microscope (SEM).

Materials and Methods

Specimen Preparation

Five different composite resins [Reflexions XLS (RFX), Grandio (GRN), Gradia Direct, (GRD), Clearfil Majesty Esthetic (CME), Ceram-X Mono (CXM)] were chosen for this study (Table I). To prepare 36 specimens from each composite resin (180 specimens in total), a round Teflon mold (1 mm in height, 10 mm in diameter) was used. During filling the composite material, the mold was covered with a transparent polyester strip (Mylar, Henry Schein, Melville, NY) and glass slides to obtain a flat surface. All specimens were polymerized for 40 s with a quartz-tungsten halogen light-curing unit (Hilux Ultra Plus, Benlioglu Dental, Ankara, Turkey) in standard mode with an intensity setting of 700 mW/cm^2. The light-polymerizing unit was calibrated before the polymerization of the composites, and the intensity of the polymerizing light source was 400 mW/cm^2 as measured by a light meter (Hilux Dental Curing Light Meter; Benlioglu Dental). The distance between the light source and specimen was standardized by holding the tip of the light-curing unit in direct contact with the upper glass slide. The upper surfaces of the specimens were then polished with abrasive paper disks (Sof Lex, 3M ESPE, St. Paul, MN) in a descending order of granulation to achieve a smooth standard surface without any oxygen inhibition layer. All specimens were then stored in distilled water for 24 h at 37°C.

Bleaching Procedure

The bleaching agents used in the study were shown in Table I. Thirty-six composite specimens from each composite resin group were randomly divided into 3 subgroups as distilled water, HP and CP group with lottery method ($n = 12$). Specimens in the first group were stored in distilled water which was refreshed daily during the 14-day testing period and this group was served as control group. Group CP specimens were treated with CP bleaching solution for 8 h per day for 14 consecutive days. Group HP specimens were exposed to HP bleaching solution for 60 min per day for 14 consecutive days according to the manufacturer's instructions. HP bleaching solution used in this study is a pre-loaded bleaching agent in a tray. To prevent the contamination of rear surface of the specimen from bleaching agent, specimens were not placed into the tray. The bleaching solution was transferred from tray to a syringe. Both of the bleaching agents were applied with a syringe (Hayat, Istanbul, Turkey) in equal amounts and uniformly spread with the help of a cotton applicator (MicroTim, Voco, Cuxhaven, Germany) on the same surfaces of the specimens every time where the thickness of the gel was approximately 1 mm and then the specimens were kept in dark containers. After daily bleaching procedure, the specimens were cleaned under running water for 1 min, dried and then stored in distilled water till the next application. At the end of 14 days, after specimens were cleaned and dried, three measurements were performed on each specimen and mean Ra values were obtained.

Roughness Test

Surface roughness average (Ra) of each specimen of three groups was measured by a single blinded evaluator with a profilometer using contact stylus tracing (Perthometer M2, Mahr GmbH; Gottingen, Germany). The diameter of the tip of the profilometer was 2.4 mm, and the accuracy was 0.5 mm/s. Tracing length was set to 5.5 mm. Three measurements were performed on the center of each sample with a cut off value of 0.25 mm. Mean surface roughness values (Ra) were calculated for each specimen. Ra describes the arithmetic mean of all

TABLE I Compositions of materials tested in this study

Materials	Code	Type	Main composition: Resin/matrix	Main composition: Filler	Manufacturer
Reflexions XLS	RFX	Nano-hybrid	Ethoxylated Bis-GMA	76 vol% (88 wt%) Glass Filler (5 μ) Amorphous Silica (0.04 μ)	Bisco, IL
Grandio	GRN	Nano-hybrid	Bis-GMA, TEGDMA	71.4 vol% (87 wt%) Ba-Al-borosilicate glass (0.1–2.5 μm) and silica nanofiller (20–60 nm)	Voco. Cuxhaven, Germany
Gradia direct	GRD	Micro-hybrid	Dimethacrylate co-monomers, UDMA	65 vol% (77 wt%) Fluoro alumino silicate glass (0.85 μm), prepolymerized filler; and silica (0.85 μm)	GC, Tokyo, Japan
Clearfil majesty esthetic	CME	Nano-hybrid	Bis-GMA hydrophobicaromatic dimethacrylates and hydrophobicaliphatic dimethacrylates	66 vol% (78 wt%) Silanated barium glass (average particle size 0.7 mm) and pre-polymerized organic filler	Kuraray, Osaka, Japan
Ceram-X mono	CXM	Ormocer based nano-hybrid	Methacrylate modified polysiloxane, dimethacrylate resin	57 vol% (76 wt%) Ba-Al-borosilicate glass (1.1–1.5 μm) and methacrylate functionalized silicon dioxide nanofiller (10 nm)	Dentsply, Konstanz, Germany
Opalescence 10% PF	CP	At-home bleaching	10% carbamide peroxide, deionized water, 0.5% potassium nitrate, 0.11% sodium fluoride ion, carbapol, glycerin		Ultradent, South Jordan, UT
Opalescence treswhite supreme	HP	At-home bleaching	10% hydrogen peroxide, potassium nitrate, fluoride		Ultradent, South Jordan, UT

values of the roughness profile over the evaluated length. The profilometer was also calibrated after every tenth specimen measurement.

SEM Evaluation

All samples were gold-sputtered before mounting on the stub of SEM (SUPRA, Carl Zeiss, Oberkochen, Germany). Surface topography of the samples was recorded at 4,000× magnification. All morphometric measurements on digital SEM images were performed by one blind calibrated examiner.

Statistical Analysis

Kruskal–Wallis analysis was used to determine any significant change in surface roughness in all groups. When significant change was detected, Mann–Whitney U test was used to make intragroup comparisons. The paired t-test was used to compare the difference in Ra values between groups before and after bleaching agent application. Values of $p < 0.05$ were accepted as statistically significant.

Results

Mean Ra values and standard deviations of composite resins in each group are shown at Table II. Results of the present study revealed that Ra values of all composite resin groups exposed to bleaching agents were statistically higher than the distilled water (control) group ($p < 0.05$). There was no significant difference between Ra values after HP and CP application within each composite group ($p > 0.05$). After bleaching, Ceram-X Mono presented the lowest surface roughness (Ra) values ($p < 0.05$), whereas RFX showed the highest Ra values among the composite resins tested after both CP and HP applications ($p < 0.05$).

Representative SEM images are shown in Figures 1–5. The SEM micrographs of all samples submitted to

TABLE II Mean Ra values (standard deviations) of the materials used in the study

	Distilled water	CP application	HP application
RFX	$0.057\ (0.02)^{A,a}$	$0.680\ (0.16)^{B,b}$	$0.503\ (0.15)^{B,e}$
GRN	$0.060\ (0.01)^{C,a}$	$0.251\ (0.17)^{D,c}$	$0.275\ (0.15)^{D,f}$
GRD	$0.063\ (0.01)^{E,a}$	$0.191\ (0.04)^{F,c}$	$0.264\ (0.19)^{F,f}$
CME	$0.062\ (0.02)^{G,a}$	$0.473\ (0.1)^{H,c}$	$0.381\ (0.18)^{H,f}$
CXM	$0.060\ (0.01)^{I,a}$	$0.110\ (0.03)^{J,d}$	$0.121\ (0.04)^{J,g}$

Different capital letters on the line and lower case letters in the column indicate statistically significant difference ($p < 0.05$).

the bleaching agents revealed an increase in surface porosity compared to the specimens stored in distilled water. The CP bleached composite resins displayed slight alterations compared to HP bleached samples. No major changes were observed for CXM samples after application of both HP and CP (Fig. 5).

Discussion

Bleaching is a widely applied cosmetic procedure to improve dental esthetics. Due to the chemical nature of this reaction, the potential effects of home bleaching agents to the teeth restored with composite resins must be considered. Especially surface roughness has been a major concern for researchers and clinicians, since increase in roughness results in plaque retention which may enhance the risk of gingival inflammation and caries formation (Bollen *et al.*, '97; Mor *et al.*, '98).

There are several methods to identify surface alterations of composite resins including contact stylus tracing, non-contact laser stylus method, scanning electron microscopy, compressed air measuring and atomic force microscopy (Whitehead *et al.*, '99). In this study, SEM evaluation was combined with contact stylus tracing method to provide both qualitative and quantitative assessments of surface roughness of composite resins.

In this study, two home-bleaching agents containing 10% HP and 10% CP were used. Results of the present study revealed that in comparison to the control group, both bleaching agents caused a statistically significant increase in surface roughness of all tested resin materials. This result is consistent with previous studies (Basting *et al.*, 2005; Gurgan and Yalcin, 2007; Rattacaso *et al.*, 2011; Wang *et al.*, 2011) which support that HP might be responsible of accelerating the hydrolytic degradation of the composite resins. Free radical per-hydroxyl produced by the decomposition of HP has a high oxidizing potential which may affect both pigment macromolecules as well as resin matrix (Alaghehmand *et al.*, 2013). Peroxides have been claimed to induce oxidative cleavage of polymer chains, resulting in bonding failure between the resin matrix and inorganic fillers (Hafez *et al.*, 2010; Rattacaso *et al.*, 2011) which may be related to increase in the surface roughness of composites resins. On the other hand, some studies (de A Silva *et al.*, 2006; Langsten *et al.*, 2002) concluded that bleaching agents had no significant effect on micro-filled, hybrid and posterior composite resin restoration surfaces. The discrepancies between the findings may be attributed to the different composite resins evaluated.

The effects of these two home bleaching agents on the surface roughness of tested composites were also compared in this study. According to SEM micrographs, CP was found to have slighter effect on the surface of all composite resins compared to HP. In a previous study (Gurgan and Yalcin, 2007), it was reported that 6.5% HP significantly increased the surface roughness of tested composite resins more than 10% CP. This might be due to the higher concentration of HP since 10% CP breaks into 3.5% HP in the mouth after clinical application (Haywood, '92) so; the HP content of 10% CP is approximately two times lower than 6.5% HP. However according to the results of the surface roughness test; there was no significant difference between Ra values after HP and CP application within each composite group. The profilometer determines the profile along three lines on the surface with the use of a tracing device, and it expresses roughness by the undulations of the profile relative to some base line whereas; SEM verifies a smaller area by going point by point and covering the whole surface (Tholt de Vasconcellos *et al.*, 2006). For this reason, disparity between the results of SEM evaluation and roughness test may be observed. Consistent with this result, Turker and Biskin (2003) reported that although there were no significant differences in surface roughness for the micro-filled composite tested, the SEM micrographs showed extensive shallow pitting localized at the center.

It has been shown in the literature that beside the bleaching agent, composition of the organic matrix; distribution, forms, content and size of filler particles

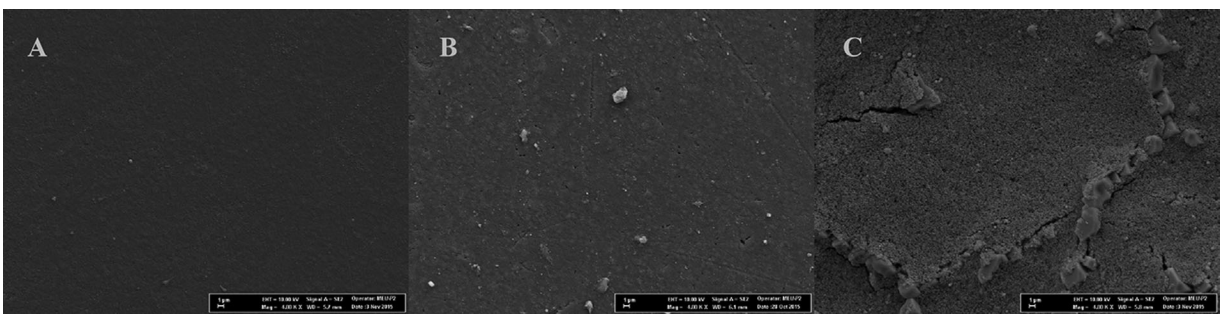

Fig 1. SEM micrographs of Reflections XLS (4,000×). A: Control group. B: CP bleached Reflections XLS. C: HP bleached Reflections XLS.

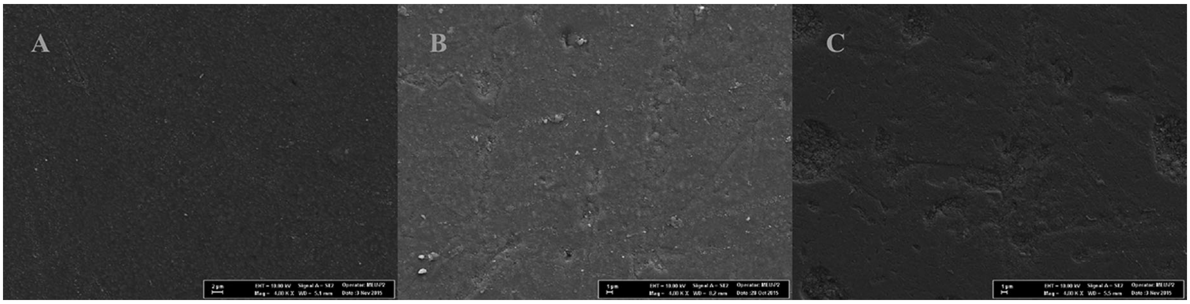

Fig 2. SEM micrographs of Grandio (4,000×). A: Control group. B: CP bleached Grandio. C: HP bleached Grandio.

might affect the performance of resin-based materials (Wattanapayungkul *et al*., 2004; Polydorou *et al*., 2006; Gurgan and Yalcin, 2007; Ulukapı, 2007; de Andrade *et al*., 2011; Wang *et al*., 2011). In this study three nano-hybrid (RFX, GRN, and CME), an ormocer based nano-hybrid (CXM) and a micro-hybrid (GRD) composite resins were evaluated. Reflexions XLS and Clearfil Majesty Esthetic showed higher Ra values after CP application compared to other composites. This result was supported by SEM micrographs. Both of these materials are based on only Bis-GMA as organic matrix. As mentioned in a previous study (Ferracane, 2006), water uptake is greater for this hydrophilic monomer compared to TEGDMA and UDMA, which may cause deterioration of resinous matrix and particle/matrix interface. The increase in surface roughness of Bis-GMA based resins after application of bleaching agents may be related to this deterioration which also reduces the super-facial integrity. Beside the organic content, the higher Ra values of RFX might have been influenced by the highest filler volume of this nano-hybrid composite. Two contradictory hypotheses exist about the interaction between filler volume and surface alteration. According to Ferracane (2006); higher volume of particles in composite formulation causes lower degree of conversion resulting in decrease of the composite hardness, whereas Rosentritt *et al*. (2005) reported that the higher filler concentration may contribute to the greater hardness resistance against bleaching agents.

Ceram X mono is a nano-ceramic composite resin which contains ormocer nanoparticles. Unlike the organic di-methacrylate monomer matrix seen in conventional composite resins, ormocer material consists of polymerizable ceramic polysiloxane matrix with a silicon dioxide inorganic backbone (Kalra *et al*., 2012). Gurbuz *et al*. (2013) reported that application of whitening strip containing 6.5% HP did not affect the surface roughness of an ormocer based and a nano-fill composite. In contrast, Gurgan and Yalcın (2007) found that whitening strip containing 6.5% HP significantly increased the surface roughness of an ormocer based resin material. The discrepancy between these results may be explained by the different application time of the bleaching agents. In the present study CXM presented the statistically lowest surface roughness values after the application of both bleaching agents. Also SEM images revealed no major changes after application of bleaching agents. This result can be attributed to the unconventional structure and lower filler volume of CXM.

It is also noteworthy that bleaching agents can alter the optical properties of composite resins. Hafez *et al*. (2010) reported that there was significantly positive correlation between color stability and surface roughness which may cause composite resins to be more susceptible to future discoloration after the application of office bleaching. The results of a previous study (Kurtulmus-Yilmaz *et al*., 2013) which evaluated the same composite resin materials and bleaching agents with the present study revealed that both HP and CP applications resulted in clinically unacceptable color changes for all composite resins and CXM which presented the lower surface roughness in this study was reported to show the highest color change. Based on these findings, for CXM it can be concluded that there

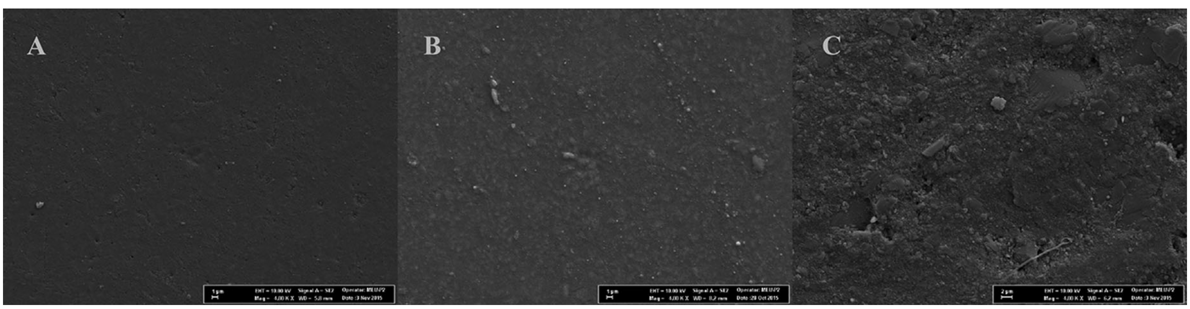

Fig 3. SEM micrographs of Gradia Direct (4,000×). A: Control group. B: CP bleached Gradia Direct. C: HP bleached Gradia Direct.

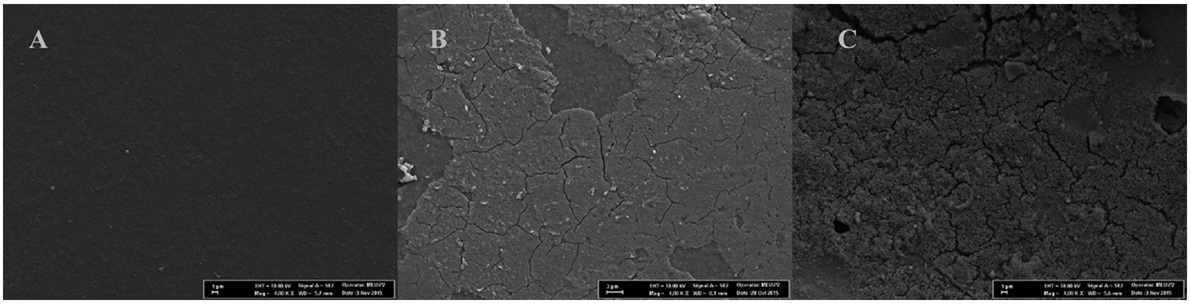

Fig 4. SEM micrographs of Clearfil Majesty Esthetic (4,000×). A: Control group. B: CP bleached Clearfil Majesty Esthetic. C: HP bleached Clearfil Majesty Esthetic.

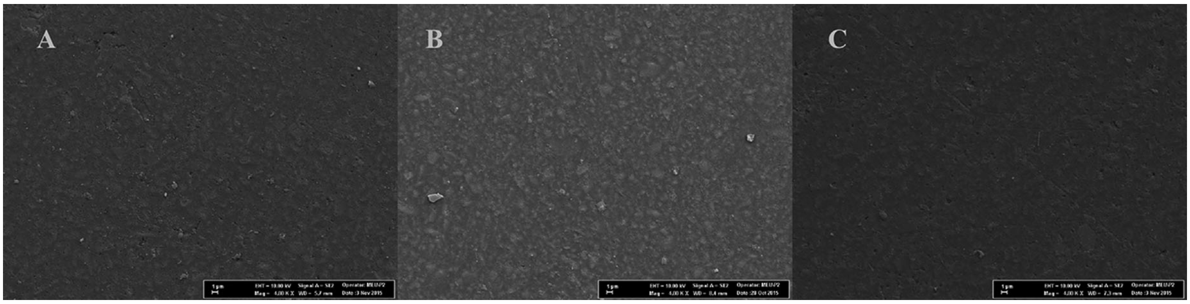

Fig 5. SEM micrographs of Ceram-X Mono (4,000×). A: Control group. B: CP bleached Ceram-X Mono. C: HP bleached Ceram-X Mono.

was no direct relationship between surface roughness and color stability. These results are in line with a previous study (Mohammadi *et al*., 2012) which has demonstrated that there was no correlation between surface roughness and color changes of micro-filled composite resins. Consistent with these results, Rattacaso *et al*. (2011) suggested that the color alteration that occurred in composite resins could be more related to the intrinsic alterations rather than on their surfaces.

Bollen *et al*. ('97) reported that the surface roughness values above the threshold of 0.2 μm resulted in increase in the accumulation of plaque and a higher risk for caries and periodontal inflammation. Ra values of all resin composite resins evaluated in this study exceeded the critical limit of 0.2 μm except for CP applied CMX group.

Conclusion

Based on the findings of this study, it can be concluded that home bleaching agents increased the surface roughness of all composite resins. According to the SEM micrographs, the effect of HP on surface roughness of tested composites was higher compared to CP. After bleaching, Ceram-X Mono presented the lowest surface roughness values whereas Reflexions XLS showed the highest Ra values among the composite resins evaluated.

Acknowledgment

We would like to thank Seher Kuru for Scanning Electron Microscope analysis.

References

Alaghehmand H, Esmaeili B, Sheibani SA. 2013. Effect of fluoride-free and fluoridated carbamide peroxide gels on the hardness and surface roughness of aesthetic restorative materials. Indian J Dent Res 24:478–483.

Basting RT, Fernandéz Y, Fernandez C, et al. 2005. Effects of a 10% carbamide peroxide bleaching agent on roughness and microhardness of packable composite resins. J Esthet Restor Dent 17:256–262.

Bollen CM, Lambrechts P, Quirynen M. 1997. Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: a review of the literature. Dent Mater 13:258–269.

Davis N. 2003. A nanotechnology composite. Compend Contin Educ Dent 24: 662, 665–667, 669–670.

de A Silva MF, Davies RM, Stewart B, et al. 2006. Effect of whitening gels on the surface roughness of restorative materials *in situ*. Dent Mater 22:919–924.

de Andrade IC, Basting RT, Lima-Arsati YB, et al. 2011. Surface roughness evaluation and shade changes of a nanofilled resin composite after bleaching and immersion in staining solutions. Am J Dent 24:245–249.

Eimar H, Siciliano R, Abdallah MN, et al. 2012. Hydrogen peroxide whitens teeth by oxidizing the organic structure. J Dent 40:25–33.

Ferracane JL. 2006. Hygroscopic and hydrolytic effects in dental polymer networks. Dent Mater 22:211–222.

Gurbuz A, Ozkan P, Yilmaz K, et al. 2013. Effect of at-home whitening strips on the surface roughness and color of a composite and an ormocer restorative material. J Prosthodont 22:69–73.

Gurgan S, Yalcin F. 2007. The effect of two different bleaching regimens on the surface roughness and hardness of tooth-colored restorative materials. Quintessence Int 38:83–87.

Hafez R, Ahmed D, Yousry M, et al. 2010. Effect of in-office bleaching on color and surface roughness of composite restoratives. Eur J Dent 4:118–127.

Hannig C, Duong S, Becker K, et al. 2007. Effect of bleaching on subsurface micro-hardness of composite and a polyacid modified composite. Dent Mater 23:198–203.

Haywood VB. 1994. Considerations and variations of dentist-prescribed, home-applied vital tooth-bleaching techniques. Compend Suppl 17:616–621.

Haywood VB. 1992. History, safety, and effectiveness of current bleaching techniques and applications of the nightguard vital bleaching technique. Quintessence Int 23:471–488.

Kalra S, Singh A, Gupta M, et al. 2012. Ormocer: an aesthetic direct restorative material; An *in vitro* study comparing the marginal sealing ability of organically modified ceramics and a hybrid composite using an ormocer-based bonding agent and a conventional fifth-generation bonding agent. Contemp Clin Dent 3:48–53.

Kurtulmus-Yilmaz S, Cengiz E, Ulusoy N, et al. 2013. The effect of home-bleaching application on the color and translucency of five resin composites. J Dent 41:70–75.

Langsten RE, Dunn WJ, Hartup GR, et al. 2002. Higher-concentration carbamide peroxide effects on surface roughness of composites. J Esthet Restor Dent 14:92–96.

Minoux M, Serfaty R. 2008. Vital tooth bleaching: biologic adverse effects-a review. Quintessence Int 39:645–659.

Mitra SB, Wu D, Holmes BN. 2003. An application of nanotechnology in advanced dental materials. J Am Dent Assoc 134:1382–1390.

Mohammadi N, Kimyai S, Abed-Kahnamoii M, et al. 2012. Effect of 15% carbamide peroxide bleaching gel on color stability of giomer and microfilled composite resin: an *in vitro* comparison. Med Oral Patol Oral Cir Bucal 17:1082–1088.

Mor C, Steinberg D, Dogan H, et al. 1998. Bacterial adherence to bleached surfaces of composite resin *in vitro*. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 86:582–586.

Polydorou O, Hellwig E, Auschill TM. 2006. The effect of different bleaching agents on the surface texture of restorative materials. Oper Dent 31:473–480.

Rattacaso RM, da Fonseca Roberti Garcia L, Aguilar FG, et al. 2011. Bleaching agent action on color stability, surface roughness and microhardness of composites submitted to accelerated artificial aging. Eur J Dent 5:143–149.

Rosentritt M, Lang R, Plein T, et al. 2005. Discoloration of restorative materials after bleaching application. Quintessence Int 36:33–39.

Tholt de Vasconcellos B, Miranda-Júnior WG, Prioli R, Thompson J, Oda M. 2006. Surface roughness in ceramics with different finishing techniques using atomic force microscope and profilometer. Oper Dent 31:442–449.

Turker SB, Biskin T. 2003. Effect of three bleaching agents on the surface properties of three different esthetic restorative materials. J Prosthet Dent 89:466–473.

Ulukapı H. 2007. Effect of different bleaching techniques on enamel surface microhardness. Quintessence Int 38:201–205.

Villalta P, Lu H, Okte Z, et al. 2006. Effects of staining and bleaching on color change of dental composite resins. J Prosthet Dent 95:137–142.

Wang L, Francisconi LF, Atta MT, et al. 2011. Effect of bleaching gels on surface roughness of nanofilled composite resins. Eur J Dent 5:173–179.

Wattanapayungkul P, Yap AU, Chooi KW, et al. 2004. The effect of home bleaching agents on the surface roughness of tooth-colored restoratives with time. Oper Dent 29:398–403.

Whitehead SA, Shearer AC, Watts DC, Wilson NH. 1999. Comparison of two stylus methods for measuring surface texture. Dent Mater 15:79–86.