ACP AMERICAN COLLEGE OF PROSTHODONTISTS
Your smile. Our specialty.

Effect of At-Home Whitening Strips on the Surface Roughness and Color of a Composite and an Ormocer Restorative Material

Ayhan Gurbuz, DDS, PhD,[1] Pelin Ozkan, DDS, PhD,[1] Kerem Yilmaz, DDS, PhD,[2] Burak Yilmaz, DDS, PhD,[3] & Rukiye Durkan, DDS, PhD[4]

[1]Professor, Department of Prosthodontics, Faculty of Dentistry, University of Ankara, Ankara, Turkey
[2]Research Assistant, Department of Prosthodontics, Faculty of Dentistry, University of Ankara, Ankara, Turkey
[3]Assistant Professor, Division of Restorative and Prosthetic Dentistry, The Ohio State University College of Dentistry, Columbus, OH
[4]Assistant Professor, Department of Prosthodontics, Faculty of Dentistry, Karadeniz Technical University, Trabzon, Turkey

Keywords
Bleaching agent; color; surface roughness.

Correspondence
Burak Yilmaz, The Ohio State University College of Dentistry, Division of Restorative and Prosthetic Dentistry, Room 3005S Postle Hall, 305 W 12th Ave., Columbus, OH 43210-1267. E-mail: yilmaz.16@osu.edu

The authors deny any conflicts of interest.

Accepted April 20, 2012

doi: 10.1111/j.1532-849X.2012.00918.x

Abstract

Purpose: Oxygenating agents like carbamide peroxide or H_2O_2 are commonly used whitening agents. They have varying influence on the color and surface roughness of resin-based restorative materials and teeth. The aim of this study was to evaluate the effect of an at-home peroxide whitening agent applied through a whitening strip on the color and surface roughness of a nanofilled composite resin and an ormocer-based resin.

Materials and Methods: Disc-shaped (2 mm thick, 10 mm diameter) nanofilled resin composite (n = 10) and ormocer (n = 10) specimens were prepared. All specimens were treated with a whitening strip. Whitening procedures were performed applying a 6.5% hydrogen peroxide whitening strip (Crest White Strips Professional) for 30 minutes twice each day for a period of 21 consecutive days. During the test intervals, the specimens were rinsed under running distilled water for 1 minute to remove the whitening agents and immersed in 37°C distilled water until the next treatment. Surface roughness and color of the specimens were measured with a profilometer and a colorimeter, respectively, before and after whitening. Color changes were calculated (ΔE) using L^*, a^*, and b^* coordinates. Repeated measures of variance analysis and Duncan test were used for statistical evaluation ($\alpha = 0.05$).

Results: The average surface roughness of composite increased from 1.4 Ra to 2.0 Ra, and from 0.8 Ra to 0.9 Ra for the ormocer material; however, these changes in roughness after whitening were not significant ($p > 0.05$). Also, when two materials were compared, the surface roughness of restorative materials was not different before and after whitening ($p > 0.05$). L^* and b^* values for each material changed significantly after whitening ($p < 0.05$). ΔE values (before/after whitening) calculated for composite (11.9) and ormocer (16.1) were not significantly different from each other ($p > 0.05$).

Conclusions: The tested whitening agent did not affect the surface roughness of either resin-based restorative material. Both materials became brighter after whitening. The behavior of the materials in the yellow/blue axis was opposite to each other after whitening. Each material had clinically unacceptable color change after whitening ($\Delta E > 5.5$); however, the magnitude of the color change of materials was similar ($p > 0.05$). According to the results of this study, with the use of materials tested, patients should be advised that existing composite restorations may bleach along with the natural teeth, and replacement of these restorations after whitening may not be required.

The esthetics of the natural dentition can be improved by whitening, and this process can be applied to intrinsically and extrinsically stained teeth. For brightening discolored teeth, the use of hydrogen peroxide or peroxide-releasing agents, such as carbamide peroxide or sodium perborate, has become a popular treatment modality.[1-12]

Night-guard whitening is commonly preferred by clinicians.[9] The clinical technique for at-home whitening involves the use of a soft, plastic, night-guard styled prosthesis as a carrier. Low concentrations of carbamide peroxide (10% to 20%) or hydrogen peroxide (3% to 7%) are used for night-guard vital whitening.[6,12-15]

Canay and Çehreli[5] evaluated the efficiency of carbamide peroxide and hydrogen peroxide, and the results revealed that differences were not statistically significant among groups bleached with carbamide peroxide ($p > 0.05$); however, statistically significant differences were reported for materials bleached with hydrogen peroxide. It was found that in comparison to carbamide peroxide, hydrogen peroxide caused more color changes in the composites tested. In Monaghan et al's study,[12] composite resins were treated with carbamide peroxide and peryhydrol urea in a proprietary base. Monaghan et al stated that all color change values were less than 2 ΔE units, and no visual color change was evident for these composite resins.

Some studies have shown significant shade improvement following at-home use of 10% carbamide peroxide gel in a tray; however, problems, including gingival irritation and tray-related tooth movement, have been reported. A whitening technique that uses flexible polyethylene strips applied directly to teeth without a tray was recently introduced. Studies found that whitening strips offer ease of use, comfort, and shorter duration of wear than do whitening tray systems. The strips provide various concentrations of peroxide distributed uniformly across the surfaces of each strip.[13,14]

High concentrations of hydrogen peroxide have been reported to cause surface roughening of teeth causing etching-like patterns.[12,16-19] Surface roughness may increase as a result of whitening treatment. Surface roughness has been a major concern for researchers and clinicians, since it is associated with plaque retention, which may lead to gingival inflammation and caries formation.[9,19,20]

Some studies have shown that the surface finish of composite restorations was not affected by at-home whitening agents,[6-14,21-29] while others reported surface changes after whitening treatment.[3] In Wattanapayungkul et al's study,[19] composite resins were treated with 10% to 15% carbamide peroxide for 8 hours/day. They reported that the effect of whitening on the surface roughness of tooth-colored materials was both material- and time-dependent. In the study by Wattanapayungkul and Yap,[20] composite, compomer, glass ionomer, and resin-modified glass ionomer cement were treated with 35% carbamide peroxide. The authors reported that the use of in-office whitening systems that employ strong oxidizing agents were not detrimental to the surface finish of materials evaluated. Tulga et al[28] reported that when dental restorative materials were treated with 35% hydrogen peroxide, they found the type of whitening gel affected the microhardness of dental materials.

Table 1 Restorative materials

Composite resins	Manufacturer	Color; polymerization time	Lot #
Charisma (nanofill): Bis-GMA (bisphenol-A-glycidylmethacrylate), TEGDMA (triethyleneglycol dimethacrylate)	Heraeus Kulzer, Hanau, Germany	A2; 40 second	15
Admira (ormocer): Bis-GMA, urethanedimetacrylate	Voco, Cuxhaven, Germany	A3; 40 second	2420

The whitening agent may have a varying influence on the color behavior of both composites and teeth or may even deteriorate restorative materials. Materials with different monomer systems, such as composites, compomers, or organically modified ceramics (ormocers) may show different resistance to whitening agents.[12-15,20-23] The technology used in the ormocer-based resin materials is different from that used in conventional composite resins. While the latter are based on SiO_2 functionalized with polymerizable organic polymer matrix, the ormocer consists of an inorganic–organic network matrix formed through polycondensation.[17]

The aim of this study was to evaluate the effect of a peroxide whitening agent applied through a whitening strip on the color and the surface roughness of a nanofilled composite resin and an ormocer-based resin. The null hypothesis of this study was that the whitening strip evaluated affected the surface roughness and color of the tested restorative materials.

Materials and methods

A nanofilled composite (n = 10) and an ormocer resin (n = 10) were tested for surface roughness and color change after at-home whitening application (Table 1). For standard fabrication of the specimens (2 mm thick, 10 mm diameter), a standardized brass mold with a screw system was used, and the composite resin and the ormocer-based resin were placed into the 2-mm-deep brass mold using a spatula. The materials were then covered with Mylar strips,[30] and glass was put on the brass mold so that the distance between the restorative materials and the polymerization probe was standardized, and excess composite was removed with the help of the glass. The halogen light polymerization unit (1000 mw/cm, Hilux, Ledmax 550, Benlioğlu, Turkey) was used for 40 seconds for polymerization of the specimens in accordance with the manufacturer's directions. The polymerization light tip contacted the specimens each time they were polymerized. The specimens were elevated with the help of a screw system and removed from the mold with a light push. The disc-shaped specimens were left in distilled water for 24 hours for the completion of polymerization. The standard temperature was 30°C to 35°C, and the relative humidity was 30% to 85% during the fabrication of the specimens.

Initial surface roughness measurements along with colorimetric measurements were performed.

Color measurements were done with a colorimeter (Minolta CR 321, Minolta C., Ltd. Radiometric Instruments Operations, Osaka, Japan) commonly used in dental research.[31-35] A polytetrafluoroethylene positioning template was used, because a change in position could affect the colorimetric determination.[36,37] The positioning template was designed according to the shape of the colorimeter so that the colorimeter was stable and repositioned at the exact same spot for each measurement. The positioning device helped to reposition the colorimeter at the same position each time the specimens were measured. The colorimeter was calibrated after every seventh specimen measurement. The colorimeter used in this study has a 3 mm measurement tip and measures each specimen in a 3 mm field.

A profilometer (Perthometer M2, Mahr GmbH; Göttingen, Germany) was used for measuring surface roughness. The diameter of the tip of the profilometer was 2.4 mm, and the accuracy was 0.5 mm/sec. Measuring path was set to 5.5 mm. Five measurements were performed with a cutoff value of 250 μm. The average surface roughness of each specimen was recorded. The profilometer was also calibrated after every seventh specimen measurement. Measurements were done on the center of each specimen.

The whitening procedures were performed on top of the specimens by placing the 6.5% hydrogen peroxide whitening strip (Crest White Strips Professional, Procter & Gamble, Cincinnati, OH) for 30 minutes twice each day. The whitening procedures were performed for a period of 21 consecutive days. During the test intervals, the specimens were rinsed under running distilled water for 1 minute to remove the whitening agents and immersed in 37°C distilled water until the next treatment. The distilled water was changed daily for all specimens. At the end of the 21 days, surface roughness and color measurements were remade.

Color is a complex subjective and objective phenomenon.[26] The CIELab system can provide statistical data of the specimens. It consists of a standard receptor, standard light source, and coordinate system. It is based on three basic colors: red (x), green (y), and blue (z). This three-dimensional system has been used since 1976 and is accepted as the most valid analysis system.[4] L^*, a^*, and b^* coordinates were recorded before and after whitening. These coordinates were used to calculate the color change ($\triangle E^*_{ab}$) of the restorative materials after whitening with the following formula:

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

The $\triangle L^*$, $\triangle a^*$, and $\triangle b^*$ values in this formula are the differences between CIE L^* a^* b^* parameters of two specimens. The value obtained with this formula represents the value of total color difference. Evaluating the total color change, information to be interpreted clinically was gathered.[4-8] Douglas et al[32] reported in their in vivo study that the predicted color difference at which 50% of dentist observers could perceive a color difference (50/50 perceptibility) was 2.6 ΔE^*_{ab} units. The predicted color difference considered color mismatch (clinically unacceptable color match) as 5.5 ΔE^*_{ab}. In this study, perceptibility threshold was accepted as 2.6 ΔE^*_{ab} units, and the clinical acceptability threshold was accepted as 5.5 ΔE^*_{ab} units.

Table 2 Color parameters before and after whitening strip exposure

Material	Whitening	L^*	a^*	b^*	ΔE
Charisma (Nanofill)	Before	79.2 (1.7)[a]	4.1(0.1)[e]	1.7 (0.3)[a]	11.9 (1.5)[f]
	After	88.7 (1.6)[b]	5.1(0.1)[e]	6.7 (0.8)[b]	
Admira (Ormocer)	Before	74.8 (1.7)[c]	4.0 (0.1)[e]	4.8 (0.3)[c]	16.1 (1.5)[f]
	After	90.5 (1.6)[d]	4.9 (0.1)[e]	3.5 (0.8)[d]	

Different letters show statistically significant differences within the variables before and after whitening.

Table 3 Surface roughness values before and after whitening strip exposure

Surface roughness (Ra [μm $\pm$ s.e.])		
	Before	After
Charisma (Nanofill)	1.4 ± 0.2^{Aa}	2.0 ± 0.3^{Aa}
Admira (Ormocer)	0.8 ± 0.2^{Aa}	0.9 ± 0.3^{Aa}

[Aa]No significant changes detected ($p < 0.05$).

The color and roughness of the specimens were evaluated before and after whitening strip exposure for each restorative material. Both the surface roughness and the color difference results were evaluated by repeated measures of variance technique ($\alpha = 0.05$). Coincidences were eliminated by Duncan test.

Results

L^*, a^*, and b^* values before and after whitening were determined, and the magnitude of color shift was calculated (ΔE). Mean L^*, a^*, b^* and ΔE values are displayed in Table 2. L^* values of both groups increased significantly after whitening ($p < 0.05$). Even though a^* values of each group increased, the changes were not significant after whitening. The b^* value of the nanofill composite group significantly increased after whitening, whereas the b^* value of ormocer significantly decreased ($p < 0.05$). According to the Duncan test, ΔE values for both restorative materials were not statistically different ($p > 0.05$).

Mean surface roughness of tested restorative materials before and after whitening is displayed in Table 3. According to the Duncan test, the surface roughness of two resin-based restorative materials did not change significantly after whitening. Also, when the two materials were compared, the surface roughness of the restorative materials was not different before and after whitening ($p > 0.05$).

Discussion

The results of this study are specific to the experimental design and the materials used. Results from a color measuring instrument can be changed because the illuminating light sent from the device can be scattered, absorbed, transmitted, reflected, and displaced in different directions because of the translucent optical properties of the restorative materials.[36] The colorimeter

used in this study was a small-diameter color measuring instrument. When using an instrument with a small aperture for both illumination and collection of light, the amount of reflected light is reduced, causing an inadequate L* value reading.[36,37] In this study, the high color difference values after whitening procedures may have occurred because of the significant changes in the L^* value of the specimens.

Other factors may influence the accuracy of the colorimeter used in this study. Unlike the flat-surfaced specimens used in this study, natural teeth have variable surface texture and anatomic variations that may influence shade measurement. The disadvantages of using a colorimeter to measure tooth color are that the instruments are designed to measure flat surfaces, and small aperture colorimeters are prone to significant edge-loss effects.[36,37] As resin specimens with flat surfaces were used in the current study, additional in vivo studies are needed before a conclusion for clinical performance can be made. The authors of this study aimed to minimize the color measurement errors, making all color measurements under the same conditions with the help of a positioning template. A color measuring device that eliminates "edge-loss" should be used in future studies to minimize the influence of measurement errors on the results.

One of the purposes of this study was to investigate the effect of the whitening agent on the surface roughness of the test materials. Therefore, the initial surface roughness was minimized with the use of Mylar strips to determine the effect of only the whitening agent on the surface roughness. It was reported in a previous study that these strips provide smoother surfaces than rubber abrasives and graded abrasive disks when used on composite resin materials.[31]

It has also been reported that surface texture might affect the accuracy of color measurements.[38] Mylar strips were applied to minimize scratches and the waviness that could affect the accuracy of the color measurements; however, the fact that only Mylar strips were used on the specimen surfaces can also be considered as a limitation of this study, since routine clinical polishing procedures were not used.

The null hypothesis of this study was partly rejected, since the surface roughness of materials tested did not significantly change; however, clinically unacceptable color changes occurred after the whitening strips were used for 21 days. The color change of both materials was over the clinically acceptable limit ($\Delta E > 5.5$). The changes mostly occurred in brightness of the materials: they became brighter after whitening procedures. The nanofill composite had a tendency to yellow, whereas ormocer had a tendency to blue after whitening. In the current study, the measured before and after surface roughness values of the ormocer were lower than the nanofilled composite resin. It should also be noted that even though the materials used in this study were different in structure, the effect of the whitening agent with respect to their total color change and surface roughness was similar.

Previous studies where hydrogen peroxide was used as a whitening agent reported different conclusions.[18,21,22,28] Wang et al used 35% hydrogen peroxide on nanofilled composites, and they detected significantly increased surface roughness. The different results of this study could be attributed to the higher concentration of the whitening agent.[18] de Andrade et al's[23] study confirmed this hypothesis with the results of their study. Different concentrations (16% and 35%) of the same hydrogen peroxide agent were used on a nanofill composite, and surface roughness was reported to be significantly higher in the 35% group than in the 16% group. Rosentritt et al[22] used hydrogen peroxide agents on different composite resin, compomer, and ormocer materials. Application of the whitening materials resulted in an increase in surface roughness. They reported that replacement of restorations was required for esthetic reasons. ΔE values were determined to be between 4.0 and 9.0 ΔE units. On the other hand, Kim et al[29] reported negligible color and surface roughness changes of three restorative composite resins after 6.5% hydrogen peroxide whitening strip application. Yalcin and Gurgan[14] used the same whitening strips on five tooth-colored restorative materials (ormocer, compomer, flowable composite, hybrid composite, and packable composite), and they reported clinically perceivable color changes of all materials after 2 weeks. Similarly, in the current study, both materials' color change was clinically perceivable. Both materials became brighter after whitening with a peroxide whitening agent and had a slight tendency toward red. Nanofill composite had a tendency to get yellower after whitening, whereas ormocer had a tendency toward blue.

According to the results of this study, patients should be advised that existing composite restorations may get brighter along with the natural teeth, and replacement of these restorations after whitening may not be required. However, a comparison with an in vivo study comparing the color changes on natural teeth and restorative materials after the whitening agents were used should be performed to see whether there is a color mismatch between natural teeth and the restorative materials after whitening.

Conclusion

Within the limitations of this in vitro study, the following conclusions were drawn:

1. After whitening treatment with a 6.5% hydrogen peroxide whitening strip, noticeable changes in color occurred for both restorative materials ($\Delta E > 5.5$).
2. Brightness of both resins increased significantly after whitening ($p < 0.05$).
3. Restorative materials showed different behaviors after whitening with respect to the blue/yellow axis, and the nanofill composite had a tendency to yellow, whereas ormocer had a tendency to blue after whitening ($p < 0.05$). Nevertheless, no significant changes in surface roughness were found between the restorative resins tested ($p > 0.05$).

Acknowledgments

The tested restorative materials were donated by the branches of the manufacturers in Turkey.

References

1. Attin T, Hannig C, Wiegand A, et al: Effect of bleaching on restorative materials and restorations—a systematic review. Dent Mater 2004;20:852-861

2. Bailey SJ, Swift EJ: Effects of home bleaching products on composite resins. Quintessence Int 1992;23:484-494
3. Belli S, Tanrıverdi FF, Belli E: Colour stability of three esthetic laminate materials against to different staining agents. J Marmara Univ Dent Fac 1997;2:643-648
4. Brewer JD, Glennon J, Garlapo DA: Spectrometric analysis of a nongreening, metal-fusing porcelain. J Prosthet Dent 1991;65:634-641
5. Canay Ş, Çehreli MC: The effect of current bleaching agents on the color of light-polymerized composites in vitro. J Prosthet Dent 2003;89:474-478
6. Garcia-Godoy F, Garcia-Godoy A, Garcia-Godoy F. Effect of bleaching gels on the surface roughness, hardness and micromorphology of composites. Gen Dent 2002;50:247-250
7. Groh CL, O'Brien WJ, Boenke KM: Differences in color between fired porcelain and shade guides. Int J Prosthodont 1992;5:510-514
8. Haywood VB, Heymann HO: Nightguard vital bleaching. Quintessence Int 1989;20:173-176
9. Jefferies SR: The art and science of abrasive finishing and polishing in restorative dentistry. Dent Clin North Am 1998;42:613-627
10. Johnston WM, Kao EC: Assessment of appearance match by visual observation and clinical colorimetry. J Dent Res 1989;68:819-822
11. Jorgensen MW, Goodkind RJ: Spectrophotometric study of five porcelain shades relative to the dimensions of color, porcelain thickness and repeated firings. Int J Prosthodont 1979;42: 96-105
12. Monaghan P, Lim E, Lautenschlager E: Effects of home bleaching preparations on composite resin color. J Prosthet Dent 1992;68:575-578
13. Mujdeci A, Gokay O: Effect of bleaching agents on the microhardness of tooth-colored restorative materials. J Prosthet Dent 2006;95:286-289
14. Yalcin F, Gurgan S: Bleaching-induced colour change in plastic filling materials. J Biomater Appl 2005;19:187-195
15. Reinhardt JW, Eivins SE, Swift EJ, et al: A clinical study of nightguard vital bleaching. Quintessence Int 1993;24:379-384
16. Villalta P, Lu H, Okte Z, et al: Effects of staining and bleaching on colour change of dental composite resins. J Prosthet Dent 2006;95:137-142
17. Yap AUJ, Lim LY, Yang TY, et al: Influence of dietary solvents on strength of nanofill and ormocer composites. Oper Dent 2005;30:129-133
18. Wang L, Francisconi LF, Atta MT, et al: Effect of bleaching gels on surface roughness of nanofilled composite resins. Eur J Dent 2011;5:173-179
19. Wattanapayungkul P, Yap AUJ, Chooi KW, et al: The effect of home bleaching agents on the surface roughness of tooth-colored restoratives with time. Oper Dent 2004;29:398-403
20. Wattanapayungkul P, Yap AUJ: Effects of in-office bleaching products on surface finish of tooth-colored restorations. Oper Dent 2003;28:15-19
21. O'Brien WJ: Dental Materials and Their Selection (ed 2). Carol Stream, IL, Quintessence, 1997
22. Rosentritt M, Lang R, Plein T, et al: Discoloration of restorative materials after bleaching application. Quintessence Int 2005;36:33-39
23. de Andrade IC, Basting RT, Lima-Arsati YB, et al: Surface roughness evaluation and shade changes of a nanofilled resin composite after bleaching and immersion in staining solutions. Am J Dent 2011;24:245-249
24. Barbieri GM, Mota EG, Rodrigues-Junior SA, et al: Effect of whitening dentifrices on the surface roughness of commercial composites. J Esthet Restor Dent 2011;23: 338-345
25. Seghi RR, Johnston WM, O'Brien WJ: Spectrophotometric analysis of color differences between porcelain systems. J Prosthet Dent 1986;56:35-40
26. Sproull RC: Color matching in dentistry: part I. The three-dimensional nature of color. J Prosthet Dent 2001;86:453-457
27. Şen D, Göller G, İşsever H: The effect of two polishing pastes on the surface roughness of bis-acryl composite and methacrylate-based resins. J Prosthet Dent 2002;88: 527-532
28. Tulga F, Özok R, Gürbüz A, et al: Effect of different types of vital bleaching agents on the microhardness of human enamel. Balkan J Stomatol 2000;4:64-66
29. Kim JH, Lee YK, Lim BS, et al: Effect of tooth-whitening strips and films on changes in color and surface roughness of resin composites. Clin Oral Investig 2004;8:118-122
30. Türker SB, Biskin T: The effect of bleaching agents on the microhardness of dental aesthetic restorative materials. J Oral Rehabil 2002;29:657-661
31. Yap AUJ, Yap SH, Teo CK, et al: Finishing/polishing of composite and compomer restoratives: effectiveness of one-step systems. Oper Dent 2004;29:275-279
32. Douglas RD, Steinhauer TJ, Wee AG: Intraoral determination of the tolerance of dentists for perceptibility and acceptability of shade mismatch. J Prosthet Dent 2007;97:200-208
33. Yilmaz B, Ozcelik TB, Wee AG: The effect of repeated firings on the color of opaque porcelain fired on different types of dental alloys used in metal-ceramic restorations: an in vitro study. J Prosthet Dent 2009;101:395-404
34. Terzioglu H, Yilmaz B, Yurdukoru B: The effect of different shades of specific luting agents and IPS Empress Ceramic thickness on overall colour. Int J Periodont Restor Dent 2009;29:499-505
35. Karaagaclioglu L, Terzioglu H, Yilmaz B, et al: In vivo and in vitro assessment of an intraoral dental colorimeter. J Prosthodont 2010;19:279-285
36. Bolt RA, Bosch JJ, Coops JC: Influence of window size in small-window color measurement, particularly of teeth. Phys Med Biol 1994;39:1133-1142
37. Haywood VB, Leonard RH, Nelson CF, et al: Effectiveness side effects and long-term status of nightguard vital bleaching. J Am Dent Assoc 1994;125:1219-1226
38. Wang H, Xiong F, Zhenhua L: Influence of varied surface texture of dentin porcelain on optical properties of porcelain specimens. J Prosthet Dent 2011;105:242-248