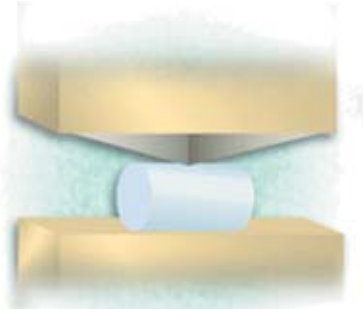# The Effect of Bleaching Agents on the Surface Hardness of Tooth Colored Restorative Materials

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Bleaching Agent is Applied to Restorative Composite   Composite Hardness is Tested

Abstract

Aim of the Study: The aim of this study was to evaluate the effect of at-home (Opalesence/Dr. kit 15%, Ultradent, Products, Inc. South Jordan, UT, USA) and in-office (Superoxol 35%, Sultan Chemists, Inc., Englewood, NJ, USA) bleaching on the surface hardness of the following tooth colored restorative materials: composite resin, Point-4 (P4), Kerr Corporation, Orange, CA, USA; ormocer, Admira (AD),VOCO, Germany; compomer Dyract AP (DY), Dentsply DeTrey GmbH, Germany; and resin modified glass ionomer cement, Fuji II LC (FL), GC Corporation, Japan.

Methodology: Sixty specimens were prepared; 15 specimens of each material (each group n = 5, control after 15 days, at-home and in-office). All specimens were stored in distilled water at room temperature for 24 hrs before testing. A universal testing machine (Micromet 2100 series micro hardness testers) was used for testing Vicker's surface hardness for the three groups for every tested material. All results were statistically analyzed with one way analysis of variance (ANOVA), Post hoc Tukey HSD tests (P<0.05), and percentage changes for Tukey.

Results: All the tested materials showed an increase in Vicker's surface hardness between base line (24 hrs) and the control group after 15 days storage in distilled water except DY which showed a decrease in surface hardness. All tested materials showed a decrease in surface hardness from control group after 15 days and both at-home and in-office bleaching agents except DY which showed increased values.

Significance: At-home as well as in-office bleaching agents have a softening effect on some tooth colored restorative material, and the patient must be aware before using them.

Keywords: Tooth bleaching, glass ionomer, composite, surface hardness, tooth colored restorative materials

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Introduction

Esthetic dentistry, particularly tooth whitening, is one of the most rapidly growing areas in dentistry, and vital tooth bleaching is a popular treatment Modality.[1, 2] Many techniques ranging from over-the-counter (OTC) products to sophisticated in-office bleaching systems are available. In-office bleaching (also called power, professional, traditional, and laser bleaching) utilizes a gel or liquid of 35% hydrogen peroxide applied to the tooth surface; allow the bleaching agent to remain on teeth for 20-30 min. A heat source, usually a visible light curing lamp, is used to enhance the bleaching process.

The procedure involves 1-3 appointments at 2-4 weeks intervals depending on the instructions for a particular product.[3] The advantages of this technique include: dentist control, avoidance of soft tissue exposure and material ingestion, reduced total treatment time, and greater potential for immediate results that may enhance patient satisfaction and motivation.[2]

Another technique available is at-home bleaching. It is called night guard vital Bleaching or NGVB. It was first described by Haywood and Heymann in 1989.[3] NGVB is an esthetic procedure where the patient, at-home, uses custom-fitted prostheses to apply a solution to lighten vital teeth. The American Dental Association's (ADA) accepted standard for the procedure recognizes the use of a 10% carbamide peroxide or CP material. The CP concentration, however, may vary from 10-22%.

Before NGVB is prescribed, a dentist must examine the patient and diagnose the causes of tooth discoloration. The patient applies the CP solution in a flexible polyvinyl custom fabricated soft prosthesis for up to 8 hrs per day over a period of 2-6 weeks.[4] Most dentists prefer at-home bleaching because in-office bleaching involves extra office time, increased liability of the staff members who are applying bleaching solutions, and diversion of staff time to the procedure. However, some dentists and personnel who are heavily involved with cosmetic procedures prefer to have control of the bleaching process in their offices.[2]

Dental practitioners are seeking a single restorative material that can accommodate a wide range of applications for both anterior and posterior restorations.[5] Composite resin materials demonstrate continual improvement in strength, wear resistance, handling, and esthetics.[6]

Resin-modified glass ionomers have the advantage of added toughness and flexibility to the relatively brittle conventional glass ionomer. The modified cements claim to have improved esthetics and mechanical properties while maintaining the benefits of conventional products, such as localized fluoride release and adhesion to the tooth structure.[7]

An additional development is polyacid-modified resin-based composite materials that set by polymerization and are based on modified resins including acid based functional groups and basic glasses. These products show interesting properties that are promising as restorative materials. Manufacturers have applied the term compomer to them, but the term polyacid-modified resin composite has been recommended for this materials.[7]

The first dental restorative material based on the Ormocer technology was marketed

in 1998.[8, 9] Ormocers are characterized by incorporation of novel organic-inorganic copolymers in the formulation that allow a modification of the mechanical properties over a wide range. Ormocers are already widely used in modern technology.[9] The Ormocer group has desirable flexural strength properties ranking them between the composite and compomer products.[10]

Restorative filling materials used in dentistry require long-term durability in the oral cavity.[11] One of the most important physical properties of restorative filling material is surface hardness.[11] The hardness of a material is a relative measure of its resistance to indentation when a specific, constant load is applied.[12] It was reported micro hardness has been shown to be an adequate indicator of the degree of conversion or polymerization of composite resin. The degree of polymerization may be related to the clinical performance of resin restorative materials.[13]

Research has been done to evaluate the effect of bleaching agents on tooth structure and to address the controversial issue regarding differences in micro hardness of control and treated teeth. Some studies have demonstrated some structural alteration on the surface of enamel while others have not.[14]

Few studies have been carried out to examine their effect on the surface hardness on restorative materials.[1] The purpose of this study was to evaluate the effect of at-home and in-office bleaching on the surface hardness of four different tooth colored restorative materials.

Materials and Methods
The tested restorative materials included Ormocer, Admira (AD), VOCO, Germany; resin modified glass ionomer cement, Fuji II LC (FL), GC Corporation, Japan; compomer Dyract AP (DY), Dentsply DeTrey GmbH, Germany; and composite resin, Point-4 (P4), Kerr Corporation, Orange, CA, USA.

Specimen Preparation
A total of 60 specimens were prepared. Fifteen specimens of each material were made with 5 specimens used for the at-home bleaching test, 5 specimens used for the in-office bleaching test, and 5 specimens served as a control group.

The specimens were prepared utilizing cylindrical Teflon split molds (8 mm internal diameter and height of 4 mm). The mold was placed on a transparent matrix strip and a glass microscopic slide. The material was injected directly into the mold until it was intentionally overfilled. The material was covered with another matrix strip

Table 1. Tested materials.

Material	Brand Name	Code	Manufacturer	Composition
Ormocer	Admira	AD	VOCO, Germany	Additive aliphatic and aromatic dimethacrylates. 78% inorganic filler material (=56% vol. microfillers).
Composite resin	Point-4	P4	Kerr Corporation, Orange, CA, USA	76% by weight (57% by volume) inorganic filler with an average particle size of 0.4 microns.
Compomer	Dyract AP	DY	DENTSPLY DeTrey GmbH, Germany	Urethan dimethacrylate TCB Resin Alkanoyl-poly-methacrylate Strontium-fluro-silicate glass Strontium fluoride Photo initiators Butyl hydroxyl toluene Iron oxide pigments
Resin modified G.I.C.	Fuji II LC	FL	GC CORPORATION, Japan	Powder: fluoroaluminisilicate glass. Liquid copolymer of acrylic acid and maleic acid, HEMA, water, camphorquinone, activator.

Table 2. Bleaching agents.

Material	Type	Manufacturer	Composition
Opalescence	At-home bleaching	Ultradent, Products, Inc. South Jordan, UT, USA	15% carbamide peroxide. Potassium nitrate 0.5%. Flouride ion 0.11%.
Superoxol	In-office bleaching	Sultan Chemists, Inc., Englewood, NJ, USA	35% hydrogen peroxide.

and a glass microscopic slide. Light pressure was applied to expel excess material from the mold. Each specimen was light-cured through the top and bottom glass slide for the duration recommended by the respective manufacturer. The set cylindrical specimen was separated from the mold. Flash was removed with a scalpel blade. All specimens were stored in distilled water at room temperature (23°C) for 24 hrs. After drying the specimens, a Universal Testing Machine (Micromet 2100 series micro hardness tester) was used for testing Vicker's surface hardness. The specimens were placed on the platform with the surface under testing facing the diamond indentor. A load of 300 g was applied to the surface for 15 seconds. Five indentations, which were not closer than 1 mm to the adjacent indentations or the margin of the specimen, were made on the surface of each specimen. The surface hardness for the control group was tested after 24 hrs and after 15 days at the end of the experiment.

At-home Bleaching Test
At-home bleaching material (Opalesence/Dr. kit 15% carbamide peroxide) as indicated in Table 2 was coated on both surfaces of the 5 specimens of each material then stored at room temperature (23°C) in a light proof container for 8 hrs as recommended by the manufacturer. The specimens were then washed and stored in distilled water. This procedure was repeated for 15 days. Surface hardness was tested at the end of the mentioned duration.

In-office Bleaching Test
Five specimens of each material were immersed in Superoxol (35% hydrogen peroxide) as presented in Table 2 for 20 min. A bleaching light (Apollo 95E, Dental Medical Diagnostic Systems, Inc., Woodland Hills, CA, USA) was positioned for each surface of the specimen and each surface was exposed during the 20 min to Superoxol

treatment to three bleeps (each bleep of 4 seconds) as recommended by the manufacturer.

The samples were washed and stored in distilled water for one week. The procedure was repeated again after one and two-week intervals as recommended by the manufacturer. (There were three treatments in total.) The samples were tested for surface hardness after 15 days. The hardness data were analyzed using two way and one way analysis of variance (ANOVA), post hoc Tukey HSD, and percentage changes in the Tukey's test.

Results
The result of the Vicker's micro hardness testing are presented in Table 3 and shown in Figures 1 and 2.

The statistical analysis showed there were significant differences between the control group, the tooth colored restorative material, and both types of bleaching agents ($p < 0.05$). The data was analyzed by two-way ANOVA. There was a significant difference between the material and the bleaching type as well as an interaction between them, so the data was further analyzed by one-way ANOVA. All tested materials showed increases in surface hardness for the 15 day group over base line (24 hrs storage) except DY which showed a decrease in surface hardness for the 15 day group from baseline (24 hrs).

The tested in-office bleaching agent appeared to have a greater softening effect (49.8%) on FL than the at-home bleaching (63.1%) and control group after 15 days (64.8%). In-office bleaching showed a statistically significant surface hardness reduction ($p < 0.05$) in comparison to at-home bleaching and the control group after 15 days.

The (P4) control group (15 days) had the highest mean hardness values (73.2) and showed

Table 3. Mean and ± SD surface hardness of tested materials and percentage changes (%).

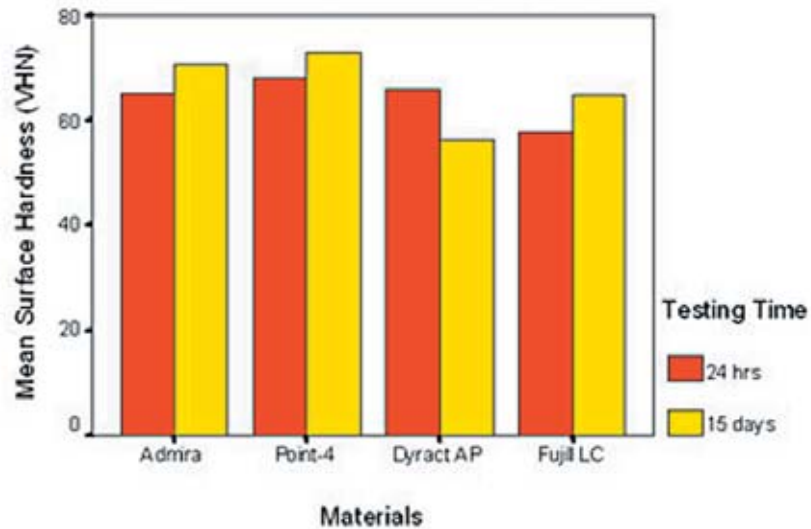| Material	Control (24 hr)	Control (15 days)	At-home bleaching	% change	In-Office bleaching	% change
Ormocer (AD)	65.30	70.58 ± 4.65	68.61 ± 5.84	2.79	69.78 ± 9.77	1.13
Composite (P4)	68.34	73.17 ± 3.67	69.73 ± 1.19	4.70	68.18 ± 1.93	6.8
Dyract AP (DY)	66.05	56.19 ± 2.65	59.65 ± .79	-6.16	65.85 ± 2.78	-17.19
Fuji II LC (FL)	57.88	64.78 ± 6.99	63.08 ± 6.59	2.62	49.79 ± 2.09	23.14

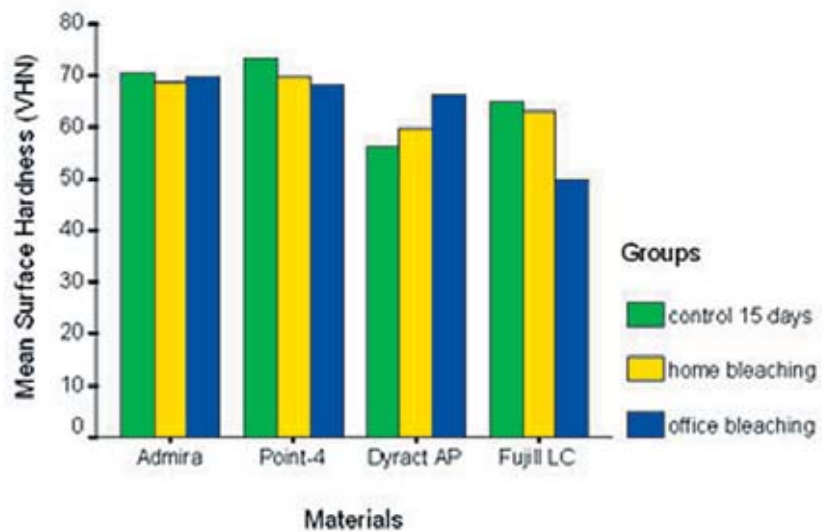**Figure 1.** Mean surface hardness of tested materials at two different periods.

Figure 2. Mean surface hardness of tested materials with different bleaching types.

a statistically significant difference (p<0.05) in comparison to the at-home (69.7) and in-office (68.2) groups. No statistically significant difference (p<0.05) was noted between the at-home and in-office bleaching groups.

AD showed no statistical significant difference (p<0.05) between at-home (68.6), in-office (69.8) bleaching, and control (70.6) groups. DY demonstrated statistical significant differences (p<0.05) between the three groups which are at-home bleaching (59.7), in-office bleaching (65.9), and the 15 day control group (56.2). The 15 day distilled water storage (56.2%) had greater softening effect on DY (66.0% at 24 hrs, water storage) than either bleaching treatment.

Discussion

Bleaching agents affect lightening of discolored tooth structure through decomposition of peroxide into free radicals. The free radicals break down large pigmented molecules, that reflect a specific wavelength of light and are responsible for the color stain in enamel, into smaller less pigmented molecules through oxidation and reduction.[14, 15]

The advantage of the in-office whitening procedure is the light source's ability to heat the hydrogen peroxide, thereby, increasing the rate of decomposition of oxygen to form oxygen free radicals and enhancing the release of stain-containing molecules.[2] Most bleaching agents that have been developed for combined use with light sources include the addition of an activator or colorant to improve light absorption or to reduce tooth heating.[2]

In addition to the oxidizing agent used in the at-home bleaching procedure an additive called carbopol (carboxy polymethelene) may be added to thicken the gel that improves adherence to the tooth surface and prolongs the release of oxygen. This additive keeps the gel contained within the tray better and slows the chemical reaction.[3]

The effect of the active agents of bleaching solutions has not been adequately investigated since there have been a limited number of studies done on their effects on restorative materials.[1, 16, 17] In addition there is a controversy in the literature where some reports indicate no significant difference in micro hardness between the bleach-treated composite resin and control group.[1] However, others report micro hardness test results indicating the treated composite resin became somewhat softer which supports our results.[16] This difference may relate to differences between specific bleaching products and/or experimental test regimes.

P4 showed an average decrease in surface hardness of 4.7% between the at-home group and the 15 day control and 6.8% (for in-office group, Table 3).

This could be contributed to the type, size, and volume fraction of the filler particles and the degree to which the filler is bonded to the resin matrix. Filler-matrix interactions appear to have a great effect on increasing the resistance of composite resin.[18] Since P4 is a micro filled composite resin, the significant reduction of surface hardness by the bleaching agents could be related to oxidation and degradation of the resinous matrix as micro filled composite resin contains a greater concentration of resinous matrix than hybrid composite resin.[17]

The resin modified GIC FL showed an average decrease in surface hardness for both at-home and in-office groups over the 15 day control group by 2.6% and 23.1% (Table 3). It was noticed the softening effect was greater with the in-office group. This outcome is predictable based on an understanding of FL setting chemistry. The filler particles of FL are mostly large particles added to smaller amounts of smaller particles.[19] Although FL is a capsule system, it contains multiple in-mixed air bubbles.[19] These intruding porosities together with filler particles are related to the poor wear resistance[19], which could be an explanation for the decrease in surface hardness with the bleaching agent.

The mean surface hardness of the compomer DY increased by 6.2% with at-home bleaching and 17.2% with in-office bleaching (Table 3). DY as

a polyacid modified resin has an ion leachable glass that is pre-reacted with a polyalkenoic acid and, subsequently, ground to small filler particles and additional un-reacted glass is added to the acidic polymeraizable monomer. Therefore, the polyacid-modified resin contains components of Glass-ionomer cement but at levels that are insufficient to produce an acid-base reaction in the dark.[19]

The matrix of polyacid-modified composite resin seems to have a different matrix from GIC, and the excess water acts as a plasticizer. Another speculation could be the particle size where DY has the smallest particle filler. Furthermore, it is one component material that does not require mixing so the inclusion of porosities is minimal. In addition the filler-matrix interactions appear to have a greater effect on increasing wear resistance.[18, 19]

AD showed statistically no significant changes in the surface hardness regardless of the bleach type. It showed mean surface hardness reductions of 2.8% with at-home bleaching and 1.1% with in-office bleaching (Table 3). This outcome is predictable as the matrix of the Ormocer is characterized by an interpenetrating network of inorganic-organic copolymer.[18] The Ormocer matrix exhibits significantly less wear than the composite matrices, thus, it has greater surface hardness.[18] It was assumed the porous filler system of some composite resin in combination with the low filler content by weight, causes the low Vicker's hardness.[9] Meanwhile. AD has a high weight percentage of filler particles (78%) which could be one of the factors related to increased surface hardness. Also, hardness depends on the degree of polymerization of the resin matrix.[12] An increased conversion rate of carbon double bonds and is associated with higher hardness values.[12]

The difference between in-office and at-home bleaching on tooth colored restorative materials in general could be related to the action of the active bleaching agent where 30% hydrogen peroxide causes a decrease in pH similar to that produced by different acidic beverages and this in turn causes demineralization of enamel.[20] Also the hydrogen peroxide is an aggressive oxidant, capable of degrading the polymer matrix of resin-rich tooth colored restorative material.[17] Carbamide peroxide (at-home bleaching) breaks into urea and hydrogen peroxide. Hydrogen peroxide in turn breaks down into free radicals, which eventually combine to form molecular oxygen and water. Some aspect of this chemical process may accelerate the hydrolytic degradation of tooth colored restorative material.[16] In addition, the presence of the thickening agent, which is said to combine with the free radical intermediates, could alter the process in some way, accounting for the differences between at-home and in-office bleaching.

The solubility and water sorption of tooth colored restorative materials are contributing factors and can cause changes in surface hardness, therefore, further investigation is recommended to study their effect.

Conclusion
The bleaching agents may soften some tooth colored restorative materials. There is a difference between the effect of at-home and in-office bleaching on the hardness of the tested material, but the clinical relevance of the present findings is uncertain. AD was not affected regardless of bleaching type. Meanwhile, DY showed increased surface hardness with both bleaching agents. Controlled clinical studies would be particularly valuable for future research.

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