

# Effects of In-Office Tooth Whiteners on Hardness of Tooth-Colored Restoratives

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## Clinical Relevance

The hardness of resin-modified glass ionomer cements, hybrid, polyacid-modified and PRG (pre-reacted glass ionomer) composites is not significantly affected by the use of in-office tooth whiteners employing the use of strong oxidizing agents.

## SUMMARY

This study investigated the effects of in-office tooth whiteners on the hardness of hybrid (Spectrum TPH), polyacid-modified (Dyract AP), PRG (Reactmer) composites and a resin-modified glass ionomer cement (Fuji II LC). Twenty-seven specimens of each material were fabricated, randomly divided into three groups of nine and treated as follows—Group 1: stored in distilled water at 37°C for three weeks (control); Group 2: treated with 35% carbamide peroxide (Opalescence Quick) for 30 minutes/week for three weeks; Group 3: treated with 35% hydrogen

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peroxide power bleach (Opalescence Xtra) for 30 minutes/week for three weeks. For Groups 2 and 3, specimens were stored in distilled water at 37°C during the hiatus periods. The treated specimens were subsequently subjected to microhardness testing (load = 500gf; dwell time = 15 seconds). Results were analyzed using ANOVA/Scheffe's test ( $p < 0.05$ ). For all treatment groups, Spectrum was significantly harder than the other materials and Reactmer was significantly harder than Dyract and Fuji II LC. The effects of in-office tooth whiteners on microhardness were material-dependent. No significant difference in hardness was observed between treatment groups for Dyract and Reactmer. For Spectrum and Fuji II LC, specimens treated with Opalescence Quick were significantly harder than those treated with Opalescence Xtra. No significant difference in hardness was observed between the control and bleached groups for all materials. The hardness of resin-modified glass-ionomer cements, hybrid, polyacid-modified and PRG composites is therefore not significantly affected by the use of 35% carbamide peroxide and 35% hydrogen peroxide in-office tooth whiteners.

## INTRODUCTION

Bleaching was first used to whiten teeth in the late 1870s (Fasanaro, 1992). Bleaching techniques may be classified by whether they involve vital or non-vital teeth and by whether the procedure is performed in the office or has an at-home component. The use of bleaching for improving the aesthetics of natural dentition has widened only after the introduction of home bleaching systems in the 1990s (Haywood & Heymann, 1989). The latter created a resurgence of bleaching, primarily because of its relative ease of application, the lower cost, its general availability to all socio-economic classes of patients, the safety of the materials used and the high percentage of successful treatment (Haywood, 1992). With the home or mouthguard bleaching technique, patients apply bleaching solutions, most of which contain 10% carbamide peroxide, to their teeth in custom-fitted plastic stents for a few hours each day. Over the past few years, in-office tooth-whitening systems employing the use of strong oxidizing agents have been re-introduced. Advantages are that it is totally under the dentist's control, the soft-tissue is generally protected from the process and it has the potential for bleaching quickly in situations in which it is effective.

There may be Class III, IV and V tooth-colored restorations on the teeth to be bleached. Although there are several reports on the effects of home bleaching systems on hybrid composites (Cooley & Burger, 1991; Bailey & Swift, 1992; Cullen, Nelson & Sandrik, 1993; Nathoo, Chmielewski & Kirkup, 1994), little is known about the effects of in-office bleaching systems on resin-modified glass-ionomer cements, polyacid-modified composites and PRG composites. PRG composites or giomers are a new class of hybrid restorative materials that employ the use of pre-reacted glass ionomer (PRG) technology. Polyacid-modified composite resins or compomers are defined as materials that contain either or both of the essential components of a glass-ionomer cement but at levels insufficient to promote acid-base cure reaction in the dark (McLean, Nicholson & Wilson, 1994). Although PRG composites contain both of the essential components of glass ionomer cements, they cannot be classified as polyacid-modified composites as the fluoroaluminosilicate glass is reacted with polyacrylic acid (that is, acid-base reaction has taken place) prior to inclusion into the urethane resin. Like hybrid and polyacid-modified composites, PRG composites are light polymerized and require the use of bonding systems for adhesion to enamel and dentin. The manufacturer's claims include fluoride release, fluoride recharge, biocompatibility, smooth surface finish, excellent aesthetics and clinical stability.

This study determined whether in-office tooth whiteners employing the use of strong oxidizing agents cause chemical softening of direct tooth colored-

restoratives. The surface hardness of the different materials after treatment was also compared.

## METHODS AND MATERIALS

The tooth-colored restoratives selected for this study included a hybrid composite (Spectrum TPH, Dentsply-De Trey, Konstanz, Germany), a polyacid-modified composite (Dyract AP, Dentsply-De Trey, Konstanz, Germany), a PRG composite (Reactmer, Shofu Inc, Kyoto, Japan) and a resin-modified glass-ionomer cement (Fuji II LC, Tokyo, Japan). All materials were of the A2 shade with the exception of Reactmer, where the lightest shade available (A3) was selected. The restorative materials were placed in the rectangular recesses (4 mm long x 3 mm wide x 2 mm deep) of customized acrylic molds and covered with acetate strips (Hawe-Neos Dental, Bioggio, Switzerland). A glass slide was then placed over this and pressure applied to extrude excess material. The restoratives were light polymerized according to manufacturers' cure times (Spectrum—20 seconds; Dyract—40 seconds; Reactmer—30 seconds; and Fuji II LC—20 seconds) through the glass slide with a PolyLUX II light-cure unit (KaVo Dental, Warthausen, Germany). The mean intensity of the light source ( $588 \pm 4$  mW/cm<sup>2</sup>) was determined with a radiometer (CureRite, EFOS Inc, Ontario Canada) prior to starting the experiment. Twenty-seven specimens of each material were fabricated and randomly divided into three groups of nine. Specimens in Group 1 were stored in distilled water at 37°C for three weeks (control). Group 2 specimens were treated with 35% carbamide peroxide (Opalescence Quick) for 30 minutes/week for three weeks and Group 3 specimens were treated with 35% hydrogen peroxide power bleach (Opalescence Xtra) for 30 minutes/week for three weeks. For Groups 2 and 3, the first bleaching treatment was conducted after seven days storage in distilled water at 37°C. Each 30 minute treatment session with Opalescence Xtra consisted of two 15 minute cycles of gel application with 20-second light exposure to enhance the action of peroxide. The bleaching gels were removed using a water jet and a standardized rinsing time of one minute. Storage medium was distilled water at 37°C during the hiatus periods.

The treated specimens were subjected to hardness testing using a digital microhardness tester (FM7, Future-Tech Corp, Tokyo, Japan). Specimens were placed centrally beneath the indenter and a 500g load was applied through the indenter for a dwell time of 15 seconds. The Knoop Hardness Number (KHN) corresponding to each indentation was computed by measuring the dimensions of the indentations and using the formula  $KHN = 1.451 \times (F/d^2)$ , where F is the test load in Newtons and d is the longer diagonal length of an indentation in millimeters. The advantage of hardness testing with the Knoop indenter compared to the Vickers indenter is the need for only one measurement

to derive the hardness number. All statistical analysis was conducted at a significance level of  $p < 0.05$ . Two-way analysis of variance (ANOVA) was performed on hardness data with restorative materials and bleaching products as main effects. One-way ANOVA and Scheffe's post-hoc tests were also performed with materials and treatment groups as independent variables to determine the effects of the in-office bleaching systems and compare the hardness of the different materials, respectively.

**RESULTS**

Table 1 and Figure 1 show the mean KHN of the materials after various treatments. Results of statistical analysis are reflected in Table 2.

Two-way ANOVA of hardness data showed significant interaction between materials and treatments. The effect of in-office tooth whiteners on hardness were therefore material dependent. No significant difference in hardness was observed between treatment groups for Dyract and Reactmer. For Spectrum and Fuji II LC, specimens treated with Opalescence Quick were significantly harder than those treated with Opalescence Xtra. No significant difference in hardness was observed between the control and bleached groups for all materials. Ranking of hardness by materials was similar for all treatment groups and was as follows: Spectrum > Reactmer > Dyract > Fuji II LC. Spectrum was significantly harder than the other materials and Reactmer was significantly harder than Dyract and Fuji II LC.

**DISCUSSION**

Hardness is defined as the resistance of a material to indentation or penetration (O'Brien, 1997). As hardness

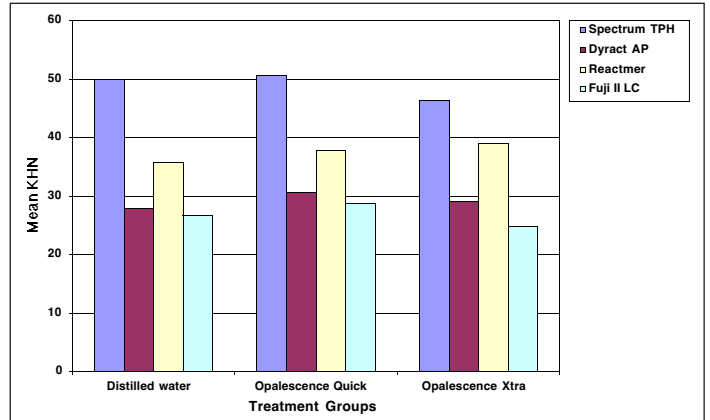


Figure 1. Treatment groups.

is related to a material's strength, proportional limit and its ability to abrade or to be abraded by opposing dental structures/materials (Anusavice, 1996), any chemical softening resulting from bleaching has implications on the clinical durability of restorations. The materials were exposed to bleaching agents after seven days to allow for post-irradiation hardening of the composites and maturation of the resin-modified glass-ionomer cement (Leung, Adishian & Johnston, 1985; Yap, 1997; Wan, Yap & Hastings, 1999). Clinically relevant bleaching regimens that followed manufacturer's recommendations were adopted for the current research. This was in contrast to several other bleaching studies in which materials were exposed continuously to bleaching products for several days to simulate cumulative effects over a time period (Monaghan, Lim & Lautenschlager, 1992; Cullen & others, 1993).

Opalescence Xtra is a premixed, syringe delivered 35% hydrogen peroxide power bleach containing carotene. The latter is a natural orange pigment found in carrots and other fruits and vegetables that can convert natural blue wavelength light of standard curing light to heat energy. Opalescence Quick is a highly viscous 35% carbamide peroxide "waiting room" whitener. It is applied to teeth using a custom-fitted, thin, scalloped tray. Carbamide peroxide degrades into approximately one-third hydrogen peroxide and two-thirds urea (Fasanaro, 1992), and hydrogen peroxide can be considered its active ingredient (Haywood, 1990). The hydrogen peroxide content in Opalescence Quick is therefore much lower than that in Opalescence Xtra. Hydrogen per-

Table 1: Mean KHN of the Different Materials After Treatment

| Materials    | Distilled Water | Opalescence Quick | Opalescence Xtra |
|--------------|-----------------|-------------------|------------------|
| Spectrum TPH | 49.84 (1.26)    | 50.58 (2.63)      | 46.38 (4.86)     |
| Dyract AP    | 27.79 (2.85)    | 30.66 (3.40)      | 29.13 (2.47)     |
| Reactmer     | 35.69 (2.20)    | 37.74 (4.34)      | 38.98 (3.11)     |
| Fuji II LC   | 26.61 (2.65)    | 28.80 (2.08)      | 24.83 (1.74)     |

Standard deviation in parenthesis.

Table 2: Results of Statistical Analysis

| Variables        |                   | Significance Spectrum TPH   |
|------------------|-------------------|---|
| Materials        | Spectrum TPH      | Opalescence Quick > Opalescence Xtra                                    |
|                  | Dyract AP         | NS  |
|                  | Reactmer          | NS  |
|                  | Fuji II LC        | Opalescence Quick > Opalescence Xtra                                    |
| Treatment Groups | Distilled water   | Spectrum TPH > All other materials<br>Reactmer > Dyract AP & Fuji II LC |
|                  | Opalescence Quick | Spectrum TPH > All other materials<br>Reactmer > Dyract AP & Fuji II LC |
|                  | Opalescence Xtra  | Spectrum TPH > All other materials<br>Reactmer > Dyract AP & Fuji II LC |

Results of one-way ANOVA/Scheffe's test ( $p < 0.05$ ) > indicates statistical significance and NS indicates no statistical significance.

oxide can form several different active oxygen species depending on temperature, pH, light, co-catalysts, presence of transitional metals and other conditions (Feinman, Madray & Yarborough, 1991). For brief periods perhydroxyl free radicals are formed:  $H_2O_2 \rightarrow HO_2^- + H^+$ . The perhydroxyl free radical  $HO_2^-$  is extremely reactive and has great oxidative power. It may break up large macromolecular stains into smaller stain molecules and by diffusion expel them to the surface. It is also thought to attach to the molecular stain in the inorganic structure as well as protein matrix (Fasanaro, 1992). The free radicals eventually combine to form molecular oxygen and water. Some aspect of this chemical process might accelerate the hydrolytic degradation of composites described by Söderholm & others (1984). Chemical softening of the restorative materials might also occur if the bleaching products have solubility parameters similar to that of the resin matrix. The Bisphenol A-glycidyl methacrylate (BisGMA) and urethane dimethacrylate (UDMA) resin polymers used in composites can be softened by chemicals with solubility parameters in the range of  $1.82 \times 10^4$  to  $2.97 \times 10^4$  ( $J/m^3$ )<sup>1/2</sup> (Wu & McKinney, 1982). As the bleaching agents and many of their components are not listed in the solvent tables of the *Polymer Handbook* (Brandup & Immergut, 1989), it is unclear whether they have solubility parameters similar to that of resins used in the various materials.

The hardness of composite resins exposed to home-use carbamide peroxide gels has been reported to increase (Cooley & Burger, 1991), decrease (Bailey & Swift, 1992) or be unchanged (Nathoo & others, 1994). Such wide variations in data suggest that some tooth-colored restorative materials may be more susceptible to alterations and some bleaching agents are more likely to cause those alterations (Swift & Perdigão, 1998). The latter may be attributed to the differences in pH between bleaching agents (Price, Sedarous & Hiltz, 2000). In this study, the effects of bleaching products on hardness were found to be material dependent. Although no significant difference in hardness was observed between treatment groups for Dyract and Reactmer, Spectrum and Fuji II LC specimens treated with Opalescence Quick were significantly harder than those treated with Opalescence Xtra. This was caused by a slight increase in hardness after treatment with Opalescence Quick and a slight softening of the materials after treatment with Opalescence Xtra. As the active ingredient for both bleaching gels is the same, it is likely that the aforementioned observation is caused by differences in gel formulation of which the presence of carotene in Opalescence Xtra is the most obvious. The exact mechanism is, however, not known and warrants further investigation.

No significant difference in hardness was observed between the control and bleached groups for all mate-

rials. Therefore, the use of in-office whiteners employing strong oxidizing agents does not cause significant chemical softening of direct tooth-colored restoratives. Both in-office and home-use bleaching products should, however, not be used indiscriminately when tooth-colored restorations are present. Bleaching agents can create visually perceptible color changes (Monaghan, Trowbridge & Lautenschlager, 1992), increase surface roughness (Cooley & Burger, 1991; Bailey & Swift, 1992) and affect adherence of certain cariogenic microorganisms to the outer surface (Mor & others, 1998) of tooth-colored restorative materials. In addition, they have been shown to reduce enamel shear bond strength (McGockin, Thurmond & Osovitz, 1992; Sung & others, 1999) and increase microleakage at gingival margins of Class V composite restorations (Crim, 1992). Patients should be informed that bleaching may accelerate the natural "aging" process of tooth-colored restoratives and must also realize that restorations might need to be replaced to ensure proper shade matching if bleaching is successful. For all treatment groups, the composite resin was significantly harder than the other hybrid materials. This was in agreement with other studies comparing the physico-mechanical properties of tooth-colored materials (Gladys & others, 1997; Berg 1998). The PRG composite was significantly harder than the polyacid-modified composite and resin-modified glass-ionomer cement.

## CONCLUSIONS

Under the conditions of this *in vitro* study:

1. The effects of in-office tooth whiteners on hardness were material dependent.
2. For Dyract AP and Reactmer, no significant difference in hardness was observed among all groups.
3. For Spectrum TPH and Fuji II LC, specimens treated with Opalescence Quick were significantly harder than those treated with Opalescence Xtra.
4. No significant difference in hardness was observed between the control and bleached groups for all materials.
5. For all groups, Spectrum TPH was significant harder than the other materials and Reactmer was significantly harder than Dyract AP and Fuji II LC.

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