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The Effect of Different Bleaching Agents on the Surface Texture of Restorative Materials

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Clinical Relevance

In-office and home bleaching agents do not cause changes that would demand replacement of the restorations when the agents are applied on the polished surfaces of aesthetic dental restorative materials. Repolishing of the composites is suggested in order to overcome possible problems that might result from slight surface changes produced by bleaching.

SUMMARY

This blind *in vitro* study evaluated the effect of a home and an in-office bleaching agent on the surface texture of different tooth-colored restorative materials.

Four composites (a hybrid, a flowable, a microhybrid and a nano-hybrid), an ormocer and a ceramic were used, and 2 bleaching agents were tested: 38% hydrogen peroxide and 15% carbamide peroxide. For 38% hydrogen peroxide, the surface morphology of the restorative materials was evaluated after the following time periods: before bleaching, after 15, 30 and 45 minutes of bleaching, 24 hours and 1 month after bleaching. For 15% carbamide peroxide, the time periods were: before bleaching, after 8 and 56 hours of bleaching and 24 hours and 1 month after bleaching. For the 4 composite materials and the ormocer, 2 samples groups were prepared; in 1 group, the specimens were polished and in the other, they stayed unpolished. For the ceramic group, polished samples were prepared. For every material, 3 samples per category and time period were prepared, respectively. Subsequently, the appropriate bleaching procedure was performed on samples of every group. Scanning electron micrographs were produced at 60x, 200x and 2000x magnifications of respective areas of the samples.

The results showed that the effect of bleaching on the surface texture was material- and time-dependent. Within the limitations of this study, it was concluded that bleaching with 38% hydrogen peroxide and 15% carbamide peroxide did not cause major surface texture changes on the polished surfaces of the restorative materials.

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DOI: 10.2341/05-75

INTRODUCTION

Attractive teeth have always been the typical patient's primary concern. In the past, dentists were often dismayed by a patient's disappointment in a "perfect restoration" painstakingly crafted of the finest gold or other material with minimized enamel reduction and long-lasting preservation of function. The patient, of course, had hoped the restoration would mimic the appearance of the original teeth. Today, by taking full advantage of new materials and techniques, dentists can often meet or even exceed such expectations (Arens, 1989; Bailey & Swift, 1992).

Bleaching is now one of the most common aesthetic treatments for adults (Anderson, 1991); but bleaching is not new. The earliest efforts to lighten teeth through bleaching in clinical practice took place more than 2 centuries ago, with bleaching agents painted directly on the tooth or packed inside a non-vital tooth. The most effective material is considered to be hydrogen peroxide (Haywood, 1992). This bleaching agent made bleaching treatment efficient for removing intrinsic stain. Most of the present-day vital bleaching materials contain hydrogen peroxide in some form or as carbamide peroxide, which breaks down to hydrogen peroxide (Fasanaro, 1992). Various methods of vital bleaching have been developed and used over the years. In-office and home bleaching are the 2 most common bleaching techniques during the last 20 years (Al Shethri & others, 2003). In-office bleaching is useful for removing discolorations by using a high concentration of hydrogen peroxide (35-38%). The dentist is in complete control of the process throughout the treatment. This provides the advantage of being able to terminate the bleaching process at any time. Studies have shown that higher concentration materials bleach teeth faster (Leonard, Sharma & Haywood, 1998; Auschill & others, 2002; Auschill & others, 2005). These materials usually work so rapidly that visible results can be observed even after a single visit. Home bleaching, over the last decade, has attracted the interest of patients and dentists due to its high success rates, ease of use and media publicity (Al-Qunaian, Matis & Cochran, 2003; Zekonis & others, 2003). The clinical technique involves the use of a soft plastic night-guard-styled splint as a carrier (Haywood & Heymann, 1991). Carbamide peroxide solutions are very unstable and immediately dissociate into their constituent parts on contact with tissue or saliva (Haywood & Heymann, 1991; Denehy & Swift, 1992; Haywood, 1992). The 10% to 16% carbamide peroxide solution dissociates into 3% to 5% hydrogen peroxide and 7% to 19% urea. Hydrogen peroxide further degrades into oxygen and water; whereas, urea degrades into ammonia and carbon dioxide.

The effects of such agents on the surface properties of restorative materials have, however, not been widely studied (Attin & others, 2004). The surface texture of a restorative material is a function of how smooth the surface is. This is an important consideration with regard to a restorative material, as the appearance of a restored tooth can be spoiled by the restoration having a matt surface finish, making it stand out from the rest of the teeth. The simplest way to assess this is by visually using a light microscope or scanning electron microscope (SEM), but it can also be numerically assessed using a profilometer. Swift (1997) and Haywood (1992) reported that nightguard vital bleaching techniques have no significant effect on the color or physical properties of porcelain or other ceramic materials, as well as amalgam or gold. Using a scanning electron microscope, Bailey and Swift (1992) observed slight surface changes in microfilled and hybrid composite after immersion for 4 hours daily in fresh bleaching gel. The SEM observations of Turker and Biskin (2003) showed only slight changes on the surface of restorative materials after home bleaching. In a study by Wattanapayungkul and others (2004), the SEM images showed numerous cracks on the surface of the restorative materials after home bleaching. Some authors (Turker & Biskin, 2003; Wattanapayungkul & Yap, 2003), who also studied the effect of bleaching on the surface roughness of restorative materials, found no significant difference in roughness between the control and bleached groups.

To date, no literature data exists on bleaching with 38% hydrogen peroxide and the effects of bleaching on currently used dental restorative materials. Therefore, this *in vitro* study evaluated the effect of an at-home and in-office bleaching agent on the surface morphology of 6 different aesthetic restorative materials (a porcelain, 4 composites and an ormocer).

METHODS AND MATERIALS

Two different bleaching agents and 6 aesthetic restorative materials were chosen for this study. The materials, product names and manufacturers are listed in Tables 1 and 2.

For preparation of the samples, the color corresponding to shade A3 was used for every material. The samples were 4.5-mm in diameter and 2-mm thick. Transparent thermoforming discs 2-mm thick were used for production of the composite and ormocer samples. Holes 4.5-mm in diameter were drilled into the

Table 1: *Restorative Materials Tested*

Material	Product Name	Manufacturer
Hybrid resin composite	Tetric Ceram	Ivoclar Vivadent AG, Schaan, Liechtenstein
Flow resin composite	Tetric Flow	Ivoclar Vivadent AG, Schaan, Liechtenstein
Microhybrid resin composite	Enamel Plus HFO	Micerium, Avegno, Italy
Nanohybrid resin composite	Filtek Supreme	3M ESPE, St Paul, MN, USA
Ormocer	Definite	Dentsply, Konstanz, Germany
Ceramic	Vitablocs Mark II for Cerec	VITA, Germany

discs and the discs were positioned on a transparent plastic matrix strip lying on a glass plate. Then, the discs were filled with the restorative materials. The samples were built-up in 1 increment (2-mm). After inserting the materials into the discs, a transparent plastic matrix strip was put over them and a glass slide was secured in order to flatten the surface. Every sample was light cured for 40 seconds in 1 step, using a halogen curing light (Elipar Highlight, 3M ESPE, Seefeld, Germany). The porcelain samples were made of Vitablocs Mark II (for Cerec), using the Cerec 3D system. The samples were polished with medium, fine and superfine Sof-Lex disks (3M ESPE) on a slow-speed handpiece in accordance with the manufacturer's instructions.

Each resin composite and ormocer consisted of 2 categories: a polished and unpolished group. The samples were polished by using the same polishing instruments used to polish the porcelain samples. Subsequently, the polished and unpolished samples of the materials were subdivided into 2 subgroups, 1 for each bleaching agent that was used. Every subgroup consisted of 3 samples for every tested time period for each of the bleaching agents. For the ceramic subgroup, only polished samples were used. For every bleaching agent, the time periods tested are listed in Table 3.

All samples were stored in distilled water at room temperature for 24 hours before any procedure was initiated. The appropriate bleaching procedure was performed on the top surface of every sample. The amount of bleaching agent used was chosen so that the top surface of the samples was covered. At the end of every bleaching procedure, the treated specimens were washed under distilled water with a soft toothbrush; they were then placed in fresh distilled water until the next application or until the end of the time period and during the 1 month post-bleaching period. The distilled water was replaced every 7 days.

After the end of every test procedure, the samples were cleaned in distilled water in an ultrasonic cleanser for 5 minutes. They were then attached to aluminum stubs (12-mm thick) with double-sided adhesive tabs. A silver print varnish (Provac AG, Balzers, Liechtenstein) was used to cover the black surface around the samples for better light reflection during the SEM procedures. The specimens were then sputter-coated with gold, and representative areas were examined with a scanning electron microscope (LEO 435VP, Cambridge, England) at 60x, 200x and 2000x magnifications. A total of 1200 pictures were made. The SEM evaluations were performed by 1 blind examiner.

The SEM observations were evaluated and classified into 3 categories:

- without any change (-)
- with minor/slight changes (+)
- with major/severe changes (+ +)

The criteria that differentiated the minor from the major changes are as follows: minor changes were those that showed negligible changes in surface texture. These changes would not require replacement of the restorations in clinical practice.

Major changes were those that showed a loss of resin parts or even surface cracks in addition to an alteration in surface morphology. A washout of the composite surface meant a major change in surface morphology. The major changes were those that were detrimental to the material and would require replacement of the material, if used in a restoration.

RESULTS

SEM examination of the restorative materials after bleaching showed observable surface changes in surface polishing and application time. Regarding the 2 different bleaching agents, their effect on surface texture of the 6 restorative materials differed for the 2 different surface treatments. Application of 38% hydrogen peroxide (Table 4) slightly changed the surface of the unpolished samples of Tetric Ceram (after 30 minutes bleaching), Enamel Plus (after 45 minutes bleaching) and Definite (after 45 minutes of bleaching). SEM observations showed severe changes on the surface of the unpolished samples of Tetric Flow after 15 minutes bleaching with 38% hydrogen peroxide. The 15 minutes

Table 2: *Bleaching Materials Tested*

Product	Bleaching Agent	Manufacturer
Opalescence Xtra Boost	38% Hydrogen Peroxide	Ultradent Products, Inc, So Jordan, UT, USA
Opalescence PF	15% Carbamide peroxide (5.4% Hydrogen peroxide)	Ultradent Products, Inc, So Jordan, UT, USA

Table 3: *Testing Periods of the Two Bleaching Agents*

Agent	Testing Periods					
Opalescence Xtra Boost	Before bleaching	After 15 minutes of bleaching	After 30 minutes of bleaching	After 45 minutes of bleaching	24 hours later	1 month later
Opalescence PF 15%	Before bleaching	After 8 hours of bleaching		After 56 hours of bleaching	24 hours later	1 month later

Table 4: *Effect of Opalescence Xtra Boost on the Restorative Materials*

		Opalescence Xtra Boost					
Material	Time	Before Bleaching	15 Minutes of Bleaching	30 Minutes of Bleaching	45 Minutes of Bleaching	Post-bleach 24 Hours	Post-bleach 1 Month
Without polishing	Tetric Ceram	—	—	+	+	+	+
	Tetric Flow	—	+ +	+ +	+ +	+ +	+ +
	Filtek Supreme	—	+	+	+ +	+ +	+ +
	Enamel Plus	—	—	—	+	+	+
	Definite	—	—	—	+	+	+
	Vitablocs Mark II						
With polishing	Tetric Ceram	—	—	—	+	+	+
	Tetric Flow	—	—	—	+	+	+
	Filtek Supreme	—	—	+	+	+	+
	Enamel Plus	—	—	—	—	—	—
	Definite	—	—	—	—	—	—
	Vitablocs Mark II	—	—	+	+	+	+

(—: without change; +: minor changes; + +: major changes)

Table 5: *Effect of Opalescence PF 15% on the Restorative Materials*

		Opalescence PF 15%				
Material	Time	Before Bleaching	8 Hours of Bleaching	56 Hours of Bleaching	Post-bleach 24 Hours	Post-bleach 1 Month
Without polishing	Tetric Ceram	—	—	+	+	+
	Tetric Flow	—	+ +	+ +	+ +	+ +
	Filtek Supreme	—	—	+	+	+
	Enamel Plus	—	+	+	+	+
	Definite	—	—	+	+	+
	Vitablocs Mark II					
With polishing	Tetric Ceram	—	—	—	—	—
	Tetric Flow	—	—	+	+	+
	Filtek Supreme	—	—	—	—	—
	Enamel Plus	—	—	—	—	—
	Definite	—	—	—	—	—
	Vitablocs Mark II	—	—	—	—	—

(—: without change; +: minor changes; + +: major changes)

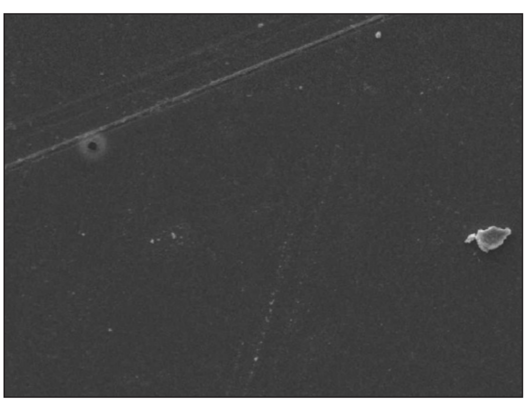

Figure 1: *Tetric Flow-Opalescence Xtra Boost without polishing, before bleaching.*

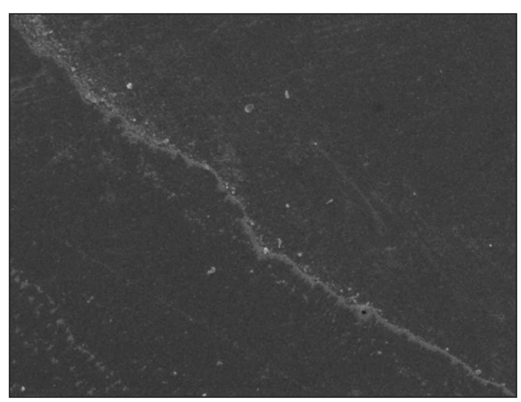

Figure 2: *Tetric Flow-Opalescence Xtra Boost without polishing, after 15 minutes bleaching, showing a change.*

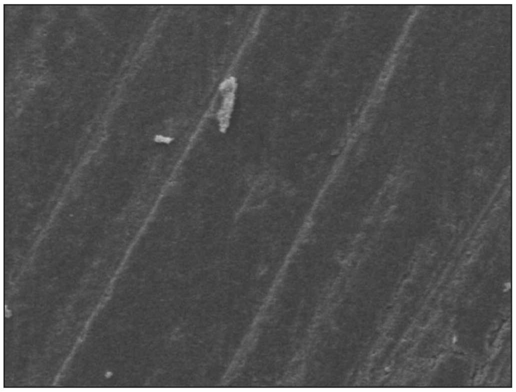

Figure 3: *Tetric Flow-Opalescence Xtra Boost with polishing, before bleaching.*

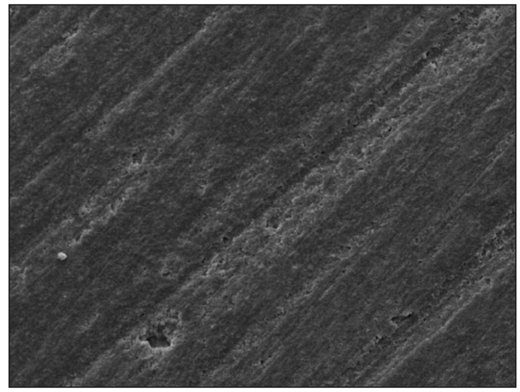

Figure 4: *Tetric Flow-Opalescence Xtra Boost with polishing, after 45 minutes bleaching, showing a change.*

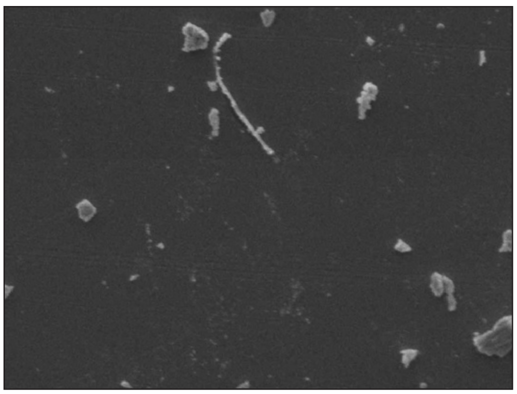

Figure 5: *Tetric Flow-Opalescence PF 15% without polishing, before bleaching.*

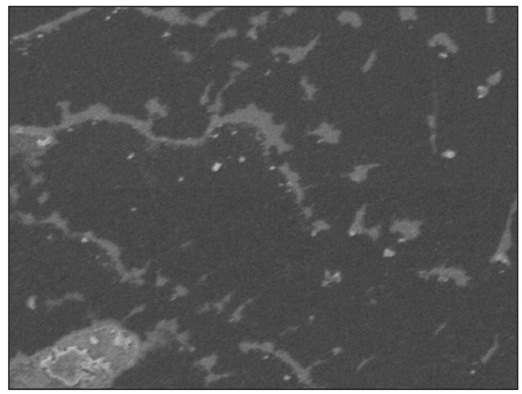

Figure 6: *Tetric Flow-Opalescence PF 15% without polishing, after 8 hours bleaching, showing a change.*

of bleaching with this bleaching agent caused minor changes on the surface of the unpolished samples of Filtek Supreme. After 45 minutes of bleaching, these minor alterations changed to major. Despite differences among the restorative materials, it was shown that all the unpolished samples that were challenged by 38% hydrogen peroxide for 45 minutes had minor surface changes.

No major changes were observed on the polished samples of many of the restorative materials tested. The surface of the polished samples of Tetric Ceram and Tetric Flow were altered slightly after 45 minutes of bleaching with 38% hydrogen peroxide; the surface of the polished samples of Filtek Supreme after 30 minutes and the polished samples of Enamel Plus and Definite were not affected by bleaching with 38% hydrogen peroxide.

In terms of 15% carbamide peroxide (Table 5), SEM micrographs also showed that the polished samples were more stable during bleaching compared to the unpolished samples. The effect of the bleaching agent was different between the restorative materials. The surfaces of the unpolished samples of Tetric Ceram, Filtek Supreme and Definite developed slight changes after 56 hours of bleaching with 15% carbamide peroxide, and the surface of Enamel Plus showed minor alterations after 8 hours of bleaching. The same application time caused severe alterations on the surface of the unpolished samples of Tetric Flow. Generally, all unpolished materials challenged by 15% carbamide peroxide for 56 hours had changes. With the polished samples, the application of 15% carbamide peroxide caused slight changes only on the surface of Tetric Flow after 56 hours. This bleaching agent did not affect the polished samples of the other restorative materials.

Regarding the ceramic samples, 38% hydrogen peroxide caused slight changes on the polished samples of this material, while 15% carbamide peroxide had no influence.

The surface alterations that were observed were estimated to be changes in surface texture, loss of resin parts or washout of the surface. No cracks were observed. The surface changes were found to remain stable 1 month after the bleaching procedure.

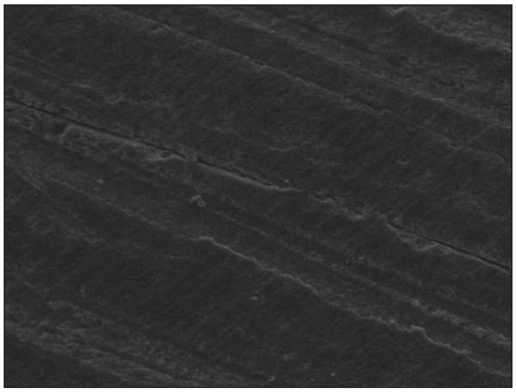

Figure 7: *Tetric Flow-Opalescence PF 15% with polishing, before bleaching.*

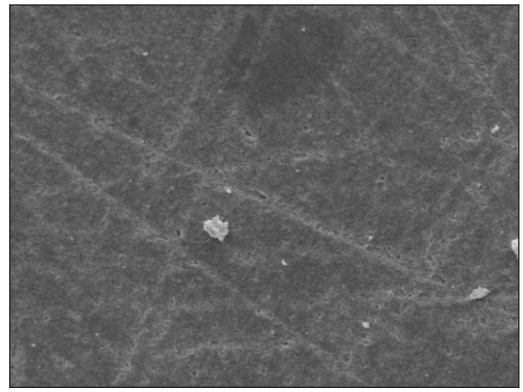

Figure 8: *Tetric Flow-Opalescence PF 15% with polishing, after 56 hours bleaching, showing a change.*

Figures 1 through 8 present SEM-pictures pre- and post-treatment of 1 restorative material that was changed by the bleaching agents.

DISCUSSION

The purpose of this *in vitro* study was to evaluate the effect of 2 different bleaching agents on the surface of 6 different aesthetic restorative materials, the effect of different application times of the bleaching agents and the effect of 2 different surface treatment situations.

Few studies have been performed that deal with the effects of bleaching agents on restorative materials. However, it is difficult to compare the results of those studies due to the variety of restorative materials used. The authors of this study know of no published studies that are available on the effects of bleaching on some of the restorative materials used in this study. Also, in the literature, only a few publications were found that addressed the effect of in-office bleaching on the surface texture of restorative materials (Wattanapayungkul & Yap, 2003).

According to SEM micrographs, Opalescence PF 15% was found to have a mild effect on the surface of materials compared to Opalescence Xtra Boost 38%. The alterations observed on the surface of the restorative materials were primarily found to be slight changes and material dependent.

The results of this study are in agreement with those of previous studies (Bailey & Swift, 1992; Duschner & others, 2004; Schemehorn, Gonzalez-Cabezas & Joiner, 2004; Turker & Biskin, 2003; Wattanapayungkul & Yap, 2003). Schemehorn and others (2004) found no significant effect of 6% hydrogen peroxide on the surface morphology of the hybrid composite tested. A study by Duschner and others (2004) revealed no significant deleterious effects on the restoration surfaces from 6% hydrogen peroxide. Wattanapayungkul and Yap (2003) only found slight differences in surface roughness between the control and bleached groups after in-office bleaching procedures. They also found differences between the materials, varying somewhat, depending on the treatment procedure. Wattanapayungkul and others (2004) showed that resin-based restoratives may be significantly roughened by the extended use of at-home bleaching agents. Their results, however, were found to be material-dependent, which is in line with the results of this study. Hybrid composites were not significantly affected by bleaching, while the polyacid-modified composite showed a dramatic increase in roughness and SEM images revealed numerous cracks and cratering. Bailey and Swift (1992) demonstrated that at-home bleaching agents (10% carbamide peroxide) caused only slight changes (some areas of cracking) to the surface of microfilled composite after immersion in fresh bleaching gel for 4 hours daily. In a study by Turker and Biskin (2003), SEM findings showed that the surface roughness of the microfilled composite was not affected by different carbamide peroxide concentrations (10-16%). In the same study, although there were no significant differences in surface roughness (with respect to controls) for the microfilled composite tested, the SEM micrographs showed extensive shallow pitting localized in the center, which was considered worse after treatment with Nite White and Rembrandt bleaching agents compared to treatment with Opalescence. This diminution suggested that the bleaching agents caused erosion on the surface of the composite matrix. Bailey and Swift (1992) suggested that the surface changes could have been caused by complex interactions within multi-component bleaching products. Roughening was suggested to result from the loss of matrix, rather than filler particles (Bailey & Swift, 1992). Wattanapayungkul and others (2004) suggested that differences between the materials could be a result of the difference in resin matrix components and filler size. Langsten and others (2002) reported that a higher-concentration carbamide peroxide bleaching agent, used as intended by the manufacturer, poses no significant risk to resin composite restoration surfaces.

Most of the products used in previous studies were home systems and over-the-counter bleaching products. The apparent discrepancies may be explained, in part, by differences in experimental methodologies and the bleaching agents used. While some researchers have adopted clinically relevant protocols, others have employed continuous exposure of restorative materials to bleaching agents over stipulated time periods (Monaghan, Lim & Lautenschlager, 1992; Cullen, Nelson & Sandrik, 1993; Turker & Biskin, 2003). Clinically relevant bleaching regimens that followed manufacturer's recommendation were adopted for this study. The frequent change of bleaching agents may also contribute to the disparity in results.

In this study, the only material always influenced by the bleaching agents that were tested was Tetric Flow. Both bleaching agents caused major alterations on the surface of unpolished samples to such degree that the unpolished restorations of this material should be replaced after bleaching, even if bleaching was made with a light bleaching agent, such as 15% carbamide peroxide. The decreased total content of inorganic fillers (68.1%wt) of Tetric Flow might be the reason that this material is more susceptible to alterations during the bleaching procedure.

In addition to Tetric Flow, SEM micrographs showed that unpolished samples of Filtek Supreme also needed to be replaced when they were challenged with 38% hydrogen peroxide for 45 minutes. Additionally, it was found that the polished groups of Filtek Supreme and the ceramic, when challenged by 38% hydrogen peroxide, showed earlier minor changes than Tetric Flow. The results pertaining to Filtek Supreme may be due to the different composition of every composite. The total content of inorganic fillers of Filtek Supreme is lower (72.5%wt) than Tetric Ceram (79%wt), Enamel Plus HFO (75%wt) and Definite (77%wt).

Composite matrices composed of BisGMA resin polymers can be softened by chemicals with similar solubility parameters (Wu & McKinney, 1982). Thus, any difference in surface roughness is expected to occur in composites with higher resin content.

The differences in effects are more pronounced in cases of higher concentrated solution (38% hydrogen peroxide). Bleaching gels contain a variety of aqueous solvents, any of which could contribute alone or in combination with other components to decrease solubility of the resin matrix. Carbamide peroxide breaks down 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 might accelerate the hydrolytic degradation of resin composites as described by Söderholm (Söderholm & others, 1984). Another aspect may be that hydrogen peroxide and free radicals have an effect on the resin-filler interface and cause a filler-matrix debonding, thereby leading to an increase in surface roughness (Wattanapayungkul & others, 2004). It is important to note that the results are material-dependent, as some tooth-colored materials are 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). Fortunately, the pH of most current bleaching products is close to neutral.

This study showed that polishing exerts an important influence on the effect of bleaching on the surface of materials. Polished samples from every material were found to be more stable than unpolished samples. Alterations on the surfaces of polished samples were found to be less compared to the alterations observed on the unpolished samples. This can be explained by the fact that the matrix finished surfaces are polymer-rich (Kao, 1989) and this layer is relatively unstable (Hachiya & others, 1984; Shintani & others, 1985). In contrast, the finished/polished surfaces are filler/glass-rich and more characteristic of the bulk material (Kao, 1989).

Within the limitations of an *in vitro* experiment, the parameter of the monomer leaching of the composite materials into the storage solution and its effect on the samples' surface must be mentioned. The effect of the storage solution on the surface texture of samples, without the parameter of bleaching, was not controlled in this study. However, the samples were stored in distilled water that was renewed every 7 days in order to minimize the effect on the monomers' leaching of the composite materials on their surface.

The surface of the ceramic used in this study was altered only slightly after bleaching with 38% hydrogen peroxide. Bleaching with 15% carbamide peroxide did not change the surface of the samples. This agrees with the findings of Turker and Biskin (2003). It is a fact that Opalescence Xtra Boost is a very powerful bleaching agent compared to different concentrations of carbamide peroxide, which may explain slight changes on the surface of the ceramic, resulting from this bleaching agent. Additionally, the way the ceramic samples were polished might explain these changes. Although the manufacturers recommend using polishing with Sof-Lex discs for this kind of ceramic, it is probably not too effective compared to polishing in the laboratory

CONCLUSIONS

1. The effect of in-office and home bleaching on the surface morphology of tooth-colored materials was material- and time-dependent.
2. Polishing of the samples had an important influence on the effect of bleaching on surface

morphology. The polished samples were found to be more stable compared to the unpolished samples in terms of the detrimental effects of bleaching agents. Good polishing of old composite restorations before bleaching is suggested in order to minimize the effect of the bleaching agents on them.

3. In clinical situations where polishing of the restorative materials should always be performed, no replacement of restorations is required after bleaching with Opalescence Xtra Boost 38% or Opalescence PF 15%. However, repolishing of the restorations after bleaching is recommended in order to overcome problems that could be caused by change of their surface morphology, such as staining, the formation of biofilm and bacterial adhesion.

(Received 23 May 2005)

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