

Penetration of the Pulp Chamber by Bleaching Agents in Teeth Restored with Various Restorative Materials

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It is thought that externally applied bleaching agents may penetrate into the pulp chamber. This study was conducted to evaluate the diffusion of peroxide bleaching agents into the pulp chamber of teeth restored with various restorative materials. Sixty-five human extracted anterior maxillary teeth were separated into the 13 groups containing 5 teeth. Five teeth (control group) were not subjected to any cavity preparation and restoration. Standardized class V cavities were prepared in the other 60 teeth and restored using composite resin (Charisma), polyacid modified composite resin (Dyract), or resin-modified glass ionomer cement (Vitremer). All teeth were sectioned 3 mm apical to the cemento-enamel junction to remove the intra-coronal pulp tissue, and the pulp chamber was filled with acetate buffer to absorb and stabilize any peroxide that might penetrate. Vestibular crown surfaces of teeth in the experimental groups were subjected to four different bleaching agents for 30 min at 37°C, whereas the teeth in the control groups were exposed only to distilled water. Then the acetate buffer solution in the pulp chamber of each tooth was removed, and the pulp chamber of each tooth was rinsed with 100 ml of distilled water twice. Leukocrystal violet and enzyme horseradish peroxidase were added to the mixture of the acetate buffer and rinse water. The optical density of the resulting blue solution was determined spectrophotometrically and converted into microgram equivalents of hydrogen peroxide. Higher hydrogen peroxide concentrations resulted in a higher pulpal peroxide penetration. The highest pulpal peroxide penetration was found in resin-modified glass ionomer cement groups, whereas composite resin groups showed the lowest pulpal peroxide penetration.

Cosmetic dentistry has focused on tooth whitening in the past few years. Three major bleaching methods for vital teeth are described as heat and light technique, microabrasion technique, and gel technique. The gel technique also involves a combination of "home and office bleach techniques." Hydrogen peroxide (H₂O₂) and carbamide peroxide are most commonly used as bleaching agents in the gel technique (1).

When a bleaching process is applied to a restored tooth the properties of the restorative materials in teeth may be affected by the bleaching agents (2–4). Kao et al. (5) reported that the contact of bleaching agents with restorative materials should be avoided if possible.

Although composite resins are the routine restorative materials, especially for anterior teeth, recently produced dental restorative materials have also been marketed for some indications. These materials consist of a mixture of components in which a photo-curable resin is incorporated into the conventional glass ionomer cement to obtain the combined characteristics of resin composites and glass ionomer cements.

These new materials have different names in literature. However, we recognize McLean et al.'s (6) categorization of these materials as resin-modified glass ionomer cement materials and polyacid-modified composite resins according to the type of their setting reaction.

In recent studies, it has been shown that both H₂O₂ and carbamide peroxide penetrate enamel and dentin, then enter the pulp chamber (7, 8), and that pulpal enzymes are significantly inhibited by H₂O₂ (9).

The purpose of this in vitro study was to evaluate the amount of penetration of peroxide bleaching agents into the pulp chamber of the teeth restored with either composite resin, polyacid-modified composite resin (compomer), or resin-modified glass ionomer cement.

MATERIALS AND METHODS

Sixty-five human, extracted, noncarious anterior maxillary teeth were used. After cleaning, the teeth were stored in distilled water.

The teeth were separated into the 13 groups, each containing 5 teeth. Five teeth which were not subjected to any cavity preparation

and restoration was evaluated as a control group. In the other 60 teeth, standardized class V cavities were prepared 2 mm deep and 3 mm in diameter at 2 mm above the cemento-enamel junction in the enamel. The cavity margins were beveled with fine grit flame-shaped diamond burs. Groups I, IV, VII, and X were restored with composite resin (Charisma; Heraeus Kulzer GmbH, Germany). Groups II, V, VIII, and XI were restored with polyacid-modified composite resin (Dyract; De Trey Dentsply Konstanz, Germany), and groups III, VI, IX, and XII were restored with resin-modified glass ionomer cement (Vitremer; 3M Dental Products, St. Paul, MN) in accordance with the manufacturer's instructions.

After polymerization or setting the restorations were finished with Soflex discs (3M Dental Products Div.) and stored 24 h in distilled water. Then the teeth were subjected to thermocycling between 5° to 55°C for 100 cycles.

The roots of all teeth were severed ~3 mm apical to the cemento-enamel junction, and the pulpal tissue was removed with a round bur. They then were washed with distilled water. An orthodontic wire was attached to each tooth by means of a light-cured composite resin. Twenty-five milliliters of 2 M acetate buffer was placed into the pulp chamber of each tooth. The vestibular crown surfaces of teeth in groups I, II, and III were immersed in 30% H₂O₂ solutions (Egaş A.Ş., Ankara, Turkey); groups IV, V, and VI in 10% carbamide peroxide (Contrast PM; Interdent, Inc., Los Angeles, CA); groups VII, VIII, and IX in 15% carbamide peroxide (Contrast PM; Interdent, Inc.); and groups X, XI, and XII in 35% carbamide peroxide (Quik Start; DenMat Corp., Santa Maria, CA). Group XIII (control group) was only exposed to distilled water (Table 1).

The acetate buffer solutions in the pulp chamber of each tooth were removed after 30 min by Pasteur pipettes and transferred to a glass tube. The pulp chamber of each tooth was rinsed twice with a 100- μ l portion of distilled water that was placed in the same glass tube and was diluted to 3.0 ml with distilled water. One hundred microliters of 0.5 mg/ml leukocrystal violet (Sigma Chemical Co., St. Louis, MO), and 50 μ l of 1 mg/ml enzyme horseradish peroxidase (Sigma) were also added to each tube according to the method described by Mottola et al (10). This procedure was repeated for each tooth.

The optical density of the resultant blue color in the tubes was measured by a UV-visible spectrophotometer (Shimadzu UV 1601) at the wavelength of 596 nm and was converted into microgram equivalents of H₂O₂. The results of measurements were evaluated statistically by analysis of variance and Duncan's test.

RESULTS

Results are summarized in Table 2. In groups in which 30% H₂O₂ (groups I, II, and III) and 35% carbamide peroxide (groups X, XI, and XII) were applied, a statistically significant difference between the peroxide penetration of the three restorative materials was found ($p < 0.01$). In groups where 10% carbamide peroxide

(groups IV, V, and VI) and 15% carbamide peroxide (groups VII, VIII, and IX) were applied, no statistically significant difference between the three restorative materials was found ($p > 0.01$).

The calculated pulpal peroxide penetration (μ g) increased parallel to the increase in free H₂O₂ concentration of bleaching agents.

The amount of pulpal peroxide was found to be 0 in the control group.

Within all the bleaching agent groups, the highest pulpal peroxide amount was observed in the teeth restored with resin-modified glass ionomer cement, whereas the lowest pulpal peroxide was found in the teeth restored by composite resin.

DISCUSSION

The recommended application period for home bleaching agents is given as a minimum of 4 h/day. For office bleaching agents it is between 5 to 30 min at intervals of a few days.

H₂O₂ breaks down into free radicals which eventually combine to form molecular oxygen and water. The oxygen oxidizes the stained areas. The effects of carbamide peroxide are similar to H₂O₂, because it ultimately breaks down into urea and H₂O₂ (1).

Although enamel is the densest tissue in the body, enamel and dentin have shown permeability to H₂O₂ (7, 11). On the other hand, Cooper et al. (8) reported that carbamide peroxide also diffuses into the pulp. All these studies were conducted on unrestored teeth.

The hazardous effects of H₂O₂ (9, 12, 13) have been observed by various researchers. For instance, Glickman et al. (14) reported an acute flare-up of a tooth after a vital bleaching procedure. However, no serious problems associated with 10% carbamide peroxide agents have been reported (1). There have been some postoperative sensitivity reports because of reversible damage to the pulp after bleaching procedures (15-17).

This study suggests that the amount of penetration might be affected by the type of restorative material. In our opinion, the penetration amount is largely due to the microleakage properties of restorative materials, because none of the restorative materials were able to completely prevent microleakage. As various studies have already shown, composite resins have lower microleakage scores than resin-modified glass ionomer cements and polyacid-modified composite resins (18, 19) because of advanced adhesive technology.

The results in this study were in conformity with the microleakage studies and show that higher pulpal peroxide penetration are found in resin-modified glass ionomer cement and polyacid-modified resin composite groups, compared with composite resin groups.

It was observed that a higher peroxide concentration caused higher pulpal peroxide penetration (μ g), which is similar to the results of previous research (7, 8). In this study the highest amount of pulpal peroxide was observed in all restorative material groups treated with 30% H₂O₂.

Hanks et al. (20) found that significant amounts of H₂O₂ diffused through the coronal surface of dentin after the application of carbamide peroxide and H₂O₂-based bleaching agents in their *in vitro* model. They also stated that the amount of diffused H₂O₂ is mostly dependent on its original concentration in the bleaching agent and the length of time the agent came into contact with the dentin. According to these researchers, at least two forces might be working against the diffusive flux of molecules of the bleaching

TABLE 1. Test groups

Groups	Charisma	Dyract	Vitremer
30% H ₂ O ₂	I	II	III
10% CP	IV	V	VI
15% CP	VII	VIII	IX
35% CP	X	XI	XII

CP, Carbamide peroxide. XIII (control group) was only exposed to distilled water.

TABLE 2. Pulpal peroxide after the application of four bleaching agents at 37°C and 30 min

Groups	n	Bleaching Agents	Free H ₂ O ₂ (%)	Pulpal Peroxide (Mean ± SD (μg))
I	5	30% H ₂ O ₂	30	25.88 ± 0.712*
II	5	30% H ₂ O ₂	30	28.30 ± 0.947*
III	5	30% H ₂ O ₂	30	31.64 ± 0.590*
IV	5	10% CP	3	5.40 ± 0.32
V	5	10% CP	3	6.32 ± 0.215
VI	5	10% CP	3	6.84 ± 0.244
VII	5	15% CP	4-5	7.38 ± 0.159
VIII	5	15% CP	4-5	7.82 ± 0.066
IX	5	15% CP	4-5	7.86 ± 0.311
X	5	35% CP	10-12	8.46 ± 0.144†
XI	5	35% CP	10-12	10.30 ± 0.095†
XII	5	35% CP	10-12	12.48 ± 0.086†
XIII	5	—	0	0

CP, Carbamide peroxide. In 10% CP and 15% CP groups, there was no statistically significant difference found between the three restorative materials ($p > 0.01$).

* In 30% H₂O₂ groups, there was a statistically significant difference between the three restorative materials ($p < 0.01$).

† In 35% CP groups, there was a statistically significant difference between the three restorative materials ($p < 0.01$).

agents toward the pulp, namely convection due to positive pulpal pressure and osmotic pressure of the gels.

It is assumed that the depth and size of the restoration, type of the base material and bonding agent that are used, and the application period of bleaching agents might affect the peroxide penetration amount. In addition, as Bowles and Uqwueneri (7) indicated in their previous studies, if peroxide derivatives are applied with heat, penetration will increase.

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