Effects of 10% carbamide peroxide on the subsurface hardness of enamel

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The purpose of this in vitro study was to determine the effects of two 10% carbamide peroxide bleaching solutions on the hardness of enamel from the surface to the dentinoenamel junction. Fifteen anterior teeth were sectioned faciolingually, and their roots were removed. Half of each crown was bleached and half served as its own control. Specimens were bleached with two commerically available 10% carbamide peroxide solutions (Proxigel and Gly-Oxide) for 24 1-hour periods. A visible color change occurred. Teeth were embedded in acrylic resin rings, sanded with progressively finer silicon carbide papers, and polished. The polishing process removed approximately 800 μm of the cut tooth surface. Specimens were tested with a microhardness tester and a Knoop diamond under a 35-g load; measurements were taken along the cut surface from the outer enamel surface to the dentinoenamel junction. Matching depths from control and test specimens were compared. For teeth treated with Gly-Oxide, no statistically significant changes in enamel hardness were evident at any depth. For teeth treated with Proxigel, no significant changes in hardness were evident at 50 μm or deeper. A statistically significant decrease in hardness was noted in the outer 25 μm of the enamel surface. It is unknown whether this decrease would have an effect clinically because the remineralizing effects of saliva should resolve any surface change.
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Introduction

Dentist-prescribed, home-applied vital tooth bleaching has become established as an effective method of lightening discolored teeth.[1,2] Many of the systems readily available today utilize 10% carbamide peroxide as the active bleaching agent.[3] However, concern has been expressed by the American Dental Association and the US Food and Drug Administration about the safety of the materials involved in the bleaching process.[4]

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Results of studies involving scanning electron microscopic analysis of teeth exposed to 10% carbamide peroxide are contradictory; Haywood et al[5] reported no change in surface morphology outside of normal enamel variations, while Covington et al[6] reported slight surface erosion. Shannon et al[7] also reported slight surface modifications of teeth treated with some 10% carbamide peroxide solutions. Several researchers have concluded that no change in hardness occurs on the surface of the enamel after exposure to 10% carbamide peroxide.[7-9] Since the active peroxide solutions travel freely through enamel and dentin,[10] it is conceivable that a change in the tooth's substructure could occur without a corresponding etch or change in hardness of the surface. Little research has specifically addressed subsurface changes in hardness of enamel that might occur during bleaching treatment.

The purpose of this in vitro study was to determine the effects of two 10% carbamide peroxide bleaching solutions on the *subsurface* hardness of enamel.

Method and materials

Two carbamide peroxide solutions were selected for study: Gly-Oxide (Marion Laboratories) and Proxigel (Reed & Carnrick). Gly-Oxide is a fast oxygen-releasing 10% carbamide peroxide solution without Carbopol (BF Goodrich). Proxigel is a slow oxygen-releasing solution which contains Carbopol. Thirty extracted, intact, nonrestored human anterior teeth were sectioned faciolingually, and their roots were removed. Half of each crown was treated and the other half served as its control.

Teeth were bleached with a solution of three drops of 10% carbamide peroxide added to 10 mL of water. After 1 hour of exposure to the solution, an additional three drops of 10% carbamide peroxide were added. After the second hour of bleaching, teeth were placed in a fresh bleaching solution. This cycle was repeated four times, and the teeth were allowed to remain overnight for 12 hours in their respective solutions. This process was repeated for 3 days, or a total of 24 exposures to 1-hour bleaching periods. The control solution used to treat the other half of each tooth was distilled water.

Fifteen specimens were bleached with a slow oxygen-releasing solution (Proxigel, pH = 5.3), and 15 specimens were bleached with a fast oxygen-releasing solution (Gly-Oxide, pH = 7.2). A visible color change occurred in the test teeth.

Teeth were embedded in acrylic resin rings 1.25-inches in diameter so that the cut surface was flush with the top of the acrylic resin ring. The teeth were sanded on the cut surface with 100-, 240-, 320-, 400-, and 600-grit silicon oxide sanding papers on a flat surface and polished to a glassy finish with 5.0-, 3.0-, 0.1- and 0.05-μm alumina polish microabrasives used on a Buehler rotating polish wheel with a Svelt cloth facing. The polishing process removed approximately 800 μm of the cut tooth surface.

Specimens were tested with a Kentron microhardness tester and a Knoop diamond under a 35-g load over 20 seconds. Hardness measurements were taken along the cut surface from the outer enamel surface to the dentinoenamel junction at depths of 25, 50, 75, 100, 150, 200, 325, 450, 575, 700, and 850 μm, or until the dentinoenamel junction was reached.

The eyepiece of the Knoop hardness tester was connected to a Sony video camera, which projected images onto a TV screen at ×2,000 magnification. The length of the indentation was measured with a millimeter ruler (typical measurements were approximately 40 mm long), and values were converted to Knoop hardness numbers (KHN).

Matching depths from control and test specimens were compared with a paired t test utilizing a Bonferronni transformation. The Bonferronni transformation adjusts for the possibility of random significance assigned to pairs when multiple t tests are taken. Results were considered significant if $P < .05$.

Results

For teeth treated with Gly-Oxide, no statistically significant changes in enamel hardness were observed between the bleached tooth half and the corresponding control tooth half at any depth. For teeth treated with Proxigel, no statistically significant changes in enamel hardness were observed between the bleached tooth half and the corresponding control tooth half at 50 μm or deeper. A significant decrease in hardness was observed for the Proxigel-treated group at the outer 25-μm measurement of the enamel surface ($P < .05$).

Results are expressed in Figs 1 and 2 as a difference between the hardness values of bleached and control teeth. A number less than zero represents a softening effect, while a number greater than zero indicates an increase in hardness. The only statistically significant value is found in the first Proxigel measurement.

Discussion

The two solutions studied are primarily different because of the presence or absence of Carbopol and the corresponding difference in pH values. Gly-Oxide has an average measured pH of 7.2, while Proxigel has an average measured pH of 5.3, a level below the generally accepted demineralization point of enamel (5.2 to 5.7).[11] Carbopol is a polymer thickening agent added to carbamide peroxide solution to increase the viscosity of the material, resulting in a bleaching solution that will stay in the tray and stick to teeth longer than the less viscous solution.[12] Whether or not the difference in results between the two solutions is related to the presence or absence of Carbopol, or to the difference in pH values, was not determined in this study. The treated dentinal surface experienced a color change that was evident both before and after removal of 800 μm of tooth structure. No testing of the effects of the bleaching on the dentinal surface was performed.

In this split-tooth in vitro study design, variations between different teeth were minimized by using one half of each tooth as its own control. Because the
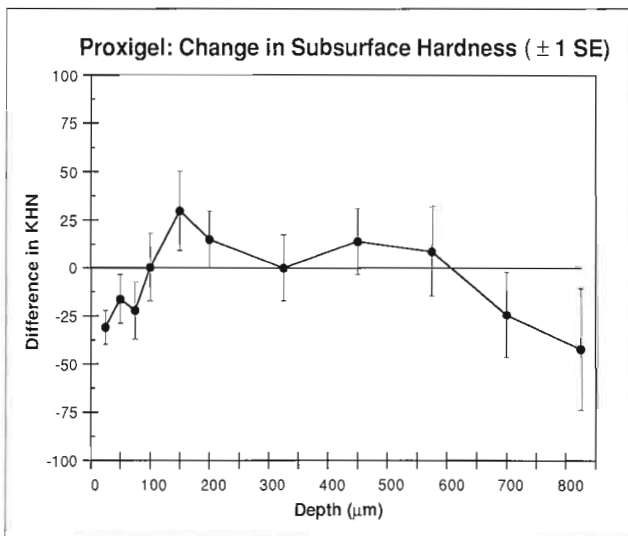
Fig 1 Proxigel: Variations in subsurface hardness (± 1 standard error) between the bleached and the unbleached tooth halves. The data represents the difference in Knoop hardness numbers (test KHN minus control KHN). A difference greater than zero indicates a relative increase in hardness after treatment, while a number less than zero indicates a relative softening effect. Only the first measurement reveals a statistically significant difference in hardness (ie, a softening effect) between treated teeth and controls.
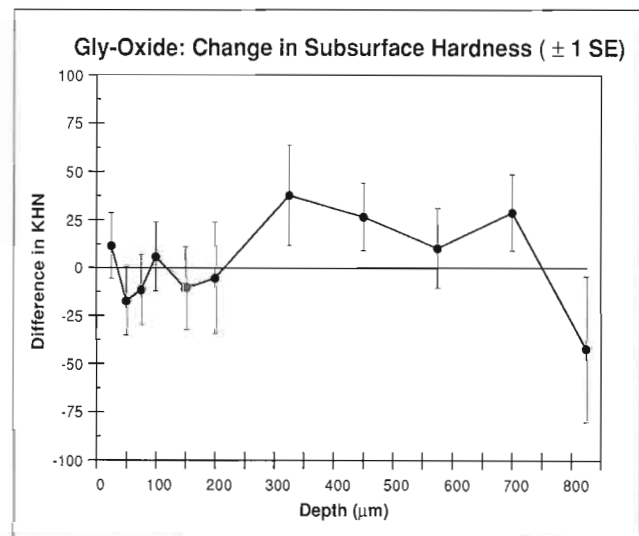

Fig 2 Gly-Oxide: Variations in subsurface hardness (± 1 standard error) between the bleached and the unbleached tooth halves. The data represent the difference in Knoop hardness numbers (test KHN minus control KHN). A difference greater than zero indicates a relative increase in hardness after treatment, while a number less than zero indicates a relative softening effect. There is no statistically significant difference between test tooth halves and controls at any depth.

bleaching solutions travel freely through enamel and dentin, each tooth had to be sectioned prior to bleaching to provide a control untouched by the bleaching solution. However, the bleaching solution then contacted the cut dentin and enamel surfaces as well as the external enamel surface. Removal of 800 μm of tooth structure from the cut surface of the tooth provided a model for evaluation of subsurface changes in the enamel. The outer 800 μm of the cross section were removed after bleaching so that subsurface changes in hardness resulted from diffusion of the peroxide from the surface enamel rather than from the cut surface of the tooth. The reduction of 800 μm represented a depth more than 30 times greater than the observed effects of 10% carbamide peroxide noted in preliminary testing.

The reduction in the Knoop hardness number at 25 μm indicates that the mineral content of the enamel decreased.[13-15] This study shows that softening of enamel occurs in vitro in only the outer 25 μm of teeth exposed to Proxigel. This effect may be overcome by remineralization actions in vivo, however, because the teeth are exposed to saliva when the bleaching guard is not in place. The depth of the softening effect may be

compared to that resulting from other common dental procedures, such as acid etching of enamel and dental prophylaxis: Thirty-seven percent phosphoric acid etches enamel to a depth of 25 μm and removes the outer 10 μm of enamel[16]; a dental prophylaxis removes 5 to 50 μm of enamel.[17]

Abrasive application of the bleaching material, such as with the use of a toothbrush or cotton-tipped applicator, may be contraindicated.[18] The potential exists for removal of tooth structure if any softening occurs during the bleach-application process. For the same reason, an advisable clinical procedure may be for patients to brush their teeth normally *before* application of the bleaching system but not to brush immediately on removal of the tray. This delay would allow any potential remineralization effects to occur.

Conclusions

Teeth treated with Gly-Oxide in vitro showed no change in Knoop hardness at any depth measured. Teeth treated with Proxigel in vitro showed a change in hardness at a depth of 25 μm only. No other hardness

changes were evident at any depth greater than 25 μm. Whether the change in hardness occurred only at a depth of 25 μm or involved the entire enamel structure from the surface to a depth of 25 μm could not be determined.

The evaluation of the clinical significance of this finding must be based on a risk-benefit ratio. Many procedures performed in dentistry and some foodstuffs damage enamel to a depth of 25 μm or greater. Even if the teeth do not remineralize in vivo, the risk to the outer 25 μm of tooth structure may be more acceptable to the patient and to the dentist then other treatment options.

To take advantage of the remineralization action of saliva, dentists should advise patients undergoing bleaching treatment not to brush with the solution and not to brush immediately on removal of the bleaching tray.

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