A STUDY OF THE BLEACHING EFFECT OF A TOOTH BLEACHING PRODUCT ON A BLACK TEA EXTRACT BY SPECTROPHOTOMETRY

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ABSTRACT

Tooth colour is determined by the complex combination of colours and optical properties of hard dental tissues (dentine, enamel) and any additional intrinsic and extrinsic stains that may be included in the tooth structure. Tooth bleaching is a non-invasive technique for tooth shade lightening by the application of tooth bleaching products for removing the discolorations that darken the tooth shade. The purpose of this research was to study the influence of two physical factors – blue light (LED, 450 nm) and electric current (2 mA) on the bleaching effect of a tooth bleaching product on black tea stain molecules, avoiding the complexity of tooth structure and the physics of hydrogen peroxide diffusion and light penetration in tooth. Spectrophotometry was used to compare the bleaching effect of H₂O₂ by the change of light absorption and optical density of the samples analyzed. Spectrophotometry manifested a decrease in the light absorption of all samples, most prominent and twice faster in the blue light exposed ones.

Key words: tooth bleaching, hydrogen peroxide, spectrophotometry

INTRODUCTION

Tooth colour is determined by the complex combination of colours and optical properties of hard dental tissues (dentine, enamel) and any additional intrinsic and extrinsic stains that may be included in the tooth structure (4,5,16).

Tooth bleaching is a non-invasive technique for tooth shade lightening by removing the discolorations that darken the tooth shade. In-office bleaching techniques are based on the bleaching action of hydrogen or carbamide peroxide, supplying in a variety of concentrations, with or without additional light irradiation recommended.

The mechanisms of bleaching involve the degradation of the extracellular matrix and oxidation of the chromophores located within enamel and dentin (2).

Literature data about the role of physical factors like temperature, light irradiation, electric current on the bleaching effect of hydrogen peroxide are controversy (1,5,17).

PURPOSE

The purpose of the study was to compare the influence of blue light (LED, 450 nm) and electric current (2 mA) on the bleaching effect of hydrogen peroxide, included in a tooth bleaching product on tea stain molecules in a black tea extract, avoiding the role and complexities of tooth structure and the physics of hydrogen peroxide (H₂O₂) diffusion and light penetration in tooth.

MATERIALS AND METHODS

UV-VIS spectroscopy is a method, mostly applied for quantitative determinations, based on the relationship between the concentration and the ef-
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Effects and intensity of monochromatic light absorbed in the range of UV spectra (200-400 nm) and VIS spectra (400-800 nm). The functional groups in the molecule, which absorb visible or UV light and add color to substance are called chromophores-organic compounds with complex bonds.

In this study the method of spectrophotometry as a method of spectroscopy was used to track the degradation of chromogenic compounds in a black tea extract subjected to the action of hydrogen peroxide, included in a tooth bleaching product. The changes in monochromatic light absorption at 390 nm and optical density of the samples analyzed were tracked in dynamics by Boeco UV/VIS Spectrophotometer model S-26 (Fig. 1) to compare the bleaching effect of a tooth bleaching product: Opalescence Boost (40% H₂O₂), Ultradent, (Fig. 2). The Spectrum Scanning mode of the spectrophotometer allowed scans to be made across any selected portion of the 198 to 1000 nm range. The auto-ranging Absorbance axis allowed scans to be commenced with no prior knowledge of the peak Absorbance level expected.

RESULTS
The results of the study were analyzed by the following graphics:

All the samples contained diluted liquid extract of black tea / Camellia sinensis /, prepared as follows: two grams of black tea were boiled in 100 ml of water for 5 min and the resulting extract was filtered. One volume of the filtrate was mixed with two parts of water and 0.5 g of the analyzed tooth bleaching product-Opalescence Boost (40% H₂O₂), Ultradent.

Five groups of samples were formed:
Group A: a control group of samples with filtrated black tea extract without tooth bleaching product
Group B: samples with filtrated black tea extract and non-activated tooth bleaching product (Opalescence Boost, Ultradent)
Group C: samples of filtrated black tea extract and tooth bleaching product (Opalescence Boost, Ultradent), activated by blue light (LED, Masterdent, 450 nm, 750 mW/cm²)
Group D: samples of filtrated black tea extract and a tooth bleaching product, activated by electric current (Ionophorator, 2mA)
Group E: For validation of the analytical method the light absorption of black tea liquid extract, mixed with H₂O₂ (30%, 25%, 20%, 15%) in the same volume ratios was measured as a function of time.

The optical density was measured during 0 to 15 min at 1 minute intervals by Boeco UV-VIS Spectrophotometer model S-26. The series was repeated as similar measurements as the bleaching of the mixture was not activated or activated by blue light /electric current (2mA).

Spectrophotometry manifested a decrease in the light absorption of all samples, most prominent in the blue light exposed ones (Group C). In this...
group the light absorption and the bleaching effect occurred for shorter time - four minutes in comparison to Group B (samples without activation) - seven minutes.

No change in light absorption was observed after the fourth and the seventh minute in both groups, respectively, which was probably due to a depletion of H$_2$O$_2$. In the samples, activated by electric current light absorption decreased gradually.

**DISCUSSION**

The bleaching power of hydrogen peroxide is due to the release of free radicals that attack the chromophores by reactions of oxidation, carboxylation and cleavage of double bonds therein (6,10):

\[
\begin{align*}
\text{H}_2\text{O}_2 & \leftrightarrow \text{H}^+ + \text{HO}_2^- \\
\text{H}_2\text{O}_2 + \text{HO}_2^- & \rightarrow \text{HO}_2^* + \text{HO}^* + \text{HO}^- \\
\text{H}_2\text{O}_2 + \text{HO}^* & \rightarrow \text{H}_2\text{O} + \text{HO}_2^*
\end{align*}
\]

Thus colour producing molecules of the chromophores, (5,15,8) or chromogenes (17) that are organic compounds having long conjugated chains with alternating simple and double bonds, often containing heteroatoms, carbonyl groups, and aromatic rings, become smaller by destroying one or more of the double bonds in the conjugated chain, by cleaving the conjugated chain, or by oxidation of other chemical moieties in the conjugated chain (8) and less colored molecules which are transferred by diffusion to the surface of the tooth and are eliminated subsequently (13).

The mechanism for tooth bleaching by hydrogen peroxide is not fully known. While it is no doubt true that the molecules are broken into shorter fragments, the detailed mechanisms for the interaction with radicals is specific to the particular molecule. The route by which the agent diffuses into the tooth structure is not yet clear because of its complexity. The way in which the radicals react with chromogenes is again varied and complex (17).

Bleaching efficacy may be increased by stimulated dissociation of the hydrogen peroxide and the formation of free radicals by physical activation, providing energy: high temperature and blue light (1). Most likely, the main mechanism of action of all light-activated bleaching procedures is the absorption of small fraction of light by the bleaching product, followed by conversion of light energy into heat. It is the effect the light or heat has on the chemical bleaching product (gel) rather than on the tooth substance itself and the chromophores it contains that may lead to an increased bleaching effect (1,12).

Halogen lamp, LED, Plasma Arc Lamp, Metal halide lamps, Lasers of different wavelengths have been introduced for the activation of the power bleaching materials (12).

Light energy also could be absorbed by photocatalysts, included in the bleaching gel and transferred to accelerate the decomposition of H$_2$O$_2$ to free oxygen radicals (9). Carotenoids, absorbed primarily at wavelengths 400-500nm, have been used as a bleaching agent activator that also serves as a red-orange colorant (1,12). The photosensitizing substance, included in Opalescence Boost is Carotene; its orange-red color is sensible to blue light and increases its absorption (1).

Under photochemically initiated reactions using light or lasers, the formation of hydroxyl radicals from hydrogen peroxide has been shown to increase (5,7). The light source can activate peroxide to accelerate the chemical redox reactions of the bleaching process (5,14).

The mechanisms by which light could enhance bleaching are different and complex:

* direct photo bleaching of chromogenic molecules by bond-breaking and loss of conjugation in their structure
* direct light induced H$_2$O$_2$-cleavage into two radicals which subsequently react with chromogenic molecules
* the chromogenes absorb the photon and transfers its energy to the hydrogen peroxide, resulting in its cleavage (17).

The mechanism by which electrical current can enhance bleaching is different. Its action leads to ionophoresis of the Hydrogen peroxide. The ionization of H$_2$O$_2$ may produce hydroxyl ions (OH), perhydroxyl ions (HOO), hydrogen ions (H$^+$), water (H$_2$O) and oxygen ions (O$^-$). Moreover, the electrochemical reactions, occurring at the cathode lead to recycling and re-synthesis of H$_2$O$_2$ (11):
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2 H₂O₂ \rightarrow 2 H₂O + O₂

2 H₂O + 2 e⁻ \rightarrow H₂ + 2 HO⁻

O₂ + 2 H₂O + 2 e⁻ \rightarrow H₂O₂ + 2 HO⁻

O₂ + 2 H⁺ + 2 e⁻ \rightarrow H₂O₂

By recycling the free radicals the bleaching process could become faster, more efficient and could require less amount of the bleaching agent without the need of renewing or reapplying it.

CONCLUSIONS

Spectrophotometry gives opportunity to evaluate the influence of physical factors (electric current and blue light) on the bleaching potential of hydrogen peroxide.

The bleaching effect of Opalescence Boost 40% H₂O₂ (Ultradent), activated by blue light or electric current on a black tea extract was equal but it occurred almost twice faster under the influence of blue light (4 minutes) than without activation (7 minutes). There was no alteration in the light absorption after that which was probably due to the depletion of H₂O₂.

By electric current activation light absorption decreased gradually. These studies will continue in vitro on extracted teeth to compare the influence of blue light and electric current on the tooth bleaching effect of hydrogen peroxide.

More rapid depletion of hydrogen peroxide in light activated samples is likely to result in faster tooth bleaching, but also it could increase the probability of postoperative hypersensitivity.

The gradual bleaching effect under the action of electric current could be preferred in view of preventing any possible postoperative hypersensitivity because of the opportunity to control the rate of decomposition of hydrogen peroxide by precisely adjusting the electric current ampere.

REFERENCES