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The effects of two 10% carbamide peroxide nightguard bleaching agents, with and without desensitizer, on enamel and sensitivity: an *in vivo* study

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Abstract: *Objectives:* This study aimed to compare the effects of two 10% carbamide peroxide (CP) agents with or without desensitizers on tooth sensitivity, colour and enamel morphological changes. *Methods:* Twenty subjects used a 10% carbamide peroxide gel with or without fluoride and potassium nitrate for 2 weeks. Sensitivity, spectrophotometric evaluation of colour and morphological analyses of replicas with scanning electron microscope (SEM) were performed before and after treatment. All data were analysed statistically. *Results:* Both bleaching agents induced sensitivity; however, the 10% CP bleaching agent with fluoride and potassium nitrate produced significantly lower sensitivity ($P < 0.05$) than the bleaching product without desensitizing agents. In spectrophotometric evaluation, no difference in bleaching effectiveness was found between the tested bleaching gels, and the SEM analysis confirmed the absence of relevant alterations of the enamel surface in both groups. *Conclusion:* The use of 10% carbamide peroxide gel with fluoride and potassium nitrate reduced the incidence of sensitivity during the bleaching treatment compared to a bleaching agent that did not contain desensitizing agents. The bleaching effectiveness of the tested products was comparable.

Key words: carbamide peroxide; dentinal sensitivity; enamel; fluoride; scanning electron microscope; tooth bleaching

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Introduction

Tooth bleaching is widely used in clinical practice (1, 2), and vital bleaching is increasingly popular. Two main approaches are available for the bleaching of vital teeth: in-office bleaching, which generally uses relatively high concentrations of bleaching agents, that is, 25–40% hydrogen peroxide (HP) or 35% carbamide peroxide (CP) applied at chairside for a short time, and at-home nightguard vital bleaching, based on lower concentrations of active agents (*i.e.* 10% of HP or 10–25% of CP) applied for a longer time (7–30 days). The at-home nightguard vital bleaching technique, in which the bleaching agents are applied daily by the patient using a custom-made tray, proposed by Haywood and Heymann at the end of the 1980s, is now used worldwide (3).

The formulation of at-home bleaching products is based primarily on the presence of CP. The CP contains 33% of HP (H_2O_2), a powerful oxidant molecule and urea (2). These two molecules act synergistically: urea degrades the enamel organic matrix, creating small spaces among the hydroxyapatite crystals, permitting HP to penetrate deeply throughout the tooth thickness (4).

Possible drawbacks of tooth bleaching are tooth sensitivity or pain, gingival irritation, and alteration of the enamel surface (2). A large percentage of patients in the first days of treatment with 10% CP show temporary tooth sensitivity (5–11), probably due to mild irritation caused by penetration of HP into the pulp, although the real inflammatory potential of bleaching treatment is controversial (12, 13). Treatment with desensitizing agents can prevent and attenuate post-bleaching sensitivity (14); for this reason, manufacturers now commercialize bleaching products blending these substances within their formulations.

The possible morphological alterations of the enamel surface due to the use of bleaching agents have been intensely investigated, but the results are controversial due to the diverse testing conditions and products (15–26). Moreover, the majority of the studies on surface analysis were performed *in vitro*, frequently not corresponding with observations *in vivo* (27). Indeed, analysis of enamel properties after bleaching *in vivo* is not simple or reproducible, and few studies used the replica technique to investigate surface morphology (28–31).

The aim of this study was to assess *in vivo* a 10% CP fluoride and potassium nitrate-containing bleaching agent compared with a similar product that did not contain desensitizing agents. The hypothesis was that there was no difference between the two tested bleaching products in terms of tooth sensitivity, colour and enamel surface morphological changes.

Study population and methodology

Inclusion and exclusion criteria

Twenty adult patients (20–50 years old, mean age 25.3 years) requesting a bleaching treatment were selected for this study. The exclusion criteria were smoking, pregnancy or breast-feeding, history of previous bleaching treatment, dentin hypersensitivity caused by caries lesions, fracture of restorations, chipped teeth, marginal gaps, post-operative sensitivity and teeth with cervical fillings, and recent use of desensitizing toothpaste. Informed consent was obtained from the patients under a protocol approved by the University of Trieste, Italy.

Study design

Before starting the bleaching treatment, all patients were subjected to a hygiene prophylaxis protocol. The bleaching agents were used with a nightguard bleaching approach. Patients were randomly divided into two groups (n = 10): Group 1 was treated with a 10% CP gel containing sodium fluoride and potassium nitrate; Group 2 was treated with a 10% CP product with no desensitizing agents. An operator not involved in the research protocol performed the randomization. Details of the allocated group were recorded on cards contained in sequentially numbered, sealed envelopes that were blindly assigned after completion of all baseline assessments.

Patients were then instructed on how to load the bleaching tray and to wear it overnight for 14 consecutive nights with an application of at least 6 h, following manufacturers' instructions.

All patients were instructed to brush their teeth with a fluoride-free toothpaste starting 2 days before the bleaching procedure. They were also asked not to use chewing gums or mouthwashes containing fluoride and to avoid drinking coffee, tea, red wine or other potentially staining beverages during treatment.

Post-operative sensitivity

Pulpal response to thermal stimuli was tested using an air spray syringe. An air jet was applied to the cervical third of the tooth through an air syringe for 5 s at a distance of 5 cm from the tooth. Adjacent teeth were isolated from the air with cotton rolls. The sensitivity test was performed before and at the end of the 2-week bleaching treatment on incisors, canines and premolars of both upper and lower dental arch of each patient, for a total of 200 measurements for each group. The pain was quantified on a scale ranging from 0 to 3 (0: no sensitivity; 1: light sensitivity; 2: moderate sensitivity; 3: severe sensitivity) (32). The sensitivity test was performed before and at the end of the 2-week bleaching treatment. Differences between baseline and post-treatment values were assessed with the Wilcoxon test. Differences between the two groups were analysed with the Mann–Whitney test. Statistical significance was set at $P < 0.05$.

Bleaching effect

Tooth colours were recorded before and after bleaching using a spectrophotometer, which was calibrated before each measurement. Colour was assessed on incisors, canines and premolars of both upper and lower dental arch of each patient, for a total of 200 measurements for each group. Colour values were expressed according to the CIE $L^*a^*b^*$ three-dimensional scale colour coordinates: lightness (L^*), magenta-green (a^*), yellow-blue (b^*). L^*value ranges from black (0) to white (100); a negative a^*value represents green, while a positive a^*value indicates magenta; a negative b^*value represents blue, and a positive b^*value indicates yellow.

The colour difference between two colour measurements is given by the Euclidean distance in CIE $L^*a^*b^*$ space (ΔE):

$$\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \qquad (33)$$

The shade evaluation was performed in the same room under the same artificial lighting conditions.

Because the data were not normally distributed, nonparametric tests were used. Differences between baseline and post-treatment values were assessed with the Wilcoxon test.

Differences between the two groups were analysed with the Mann–Whitney test. Statistical significance was set at $P < 0.05$.

Effect on enamel surface

Before bleaching, the right-upper incisor of each patient was cleaned with a prophylaxis paste for 10 s, thoroughly rinsed and air-dried for 10 s. Then, an impression of the surface, which served as negative control, was taken using a polyvinylsiloxane impression material. A second impression of the right-upper central incisor was taken similarly at the end of the 2-week bleaching treatment. Replicas were prepared by pouring impressions with an epoxy resin, gold-sputtered and visualized with a scanning electron microscope (SEM) at 500–2000× magnifications. Replicas of two caries-free premolars, extracted for orthodontic reasons, were used as positive controls: premolars were etched on the vestibular surface with 37% phosphoric acid for 30 s immediately after extraction, and impressions and replicas were prepared as described above.

Results

Post-operative sensitivity

Both bleaching treatments significantly increased sensitivity (10% carbamide peroxide gel with fluoride and potassium nitrate: 0.38 ± 0.74; 10% carbamide peroxide gel without desensitizing agents: 0.53 ± 0.78; Fig. 1) compared to baseline (0.17 ± 0.38; $P < 0.05$). The use of a 10% CP fluoride and a potassium nitrate-containing bleaching agent produced significantly lower sensitivity ($P < 0.05$) than did the bleaching product that did not contain desensitizing agents.

None of the patients interrupted the bleaching protocol or required the use of pain relievers.

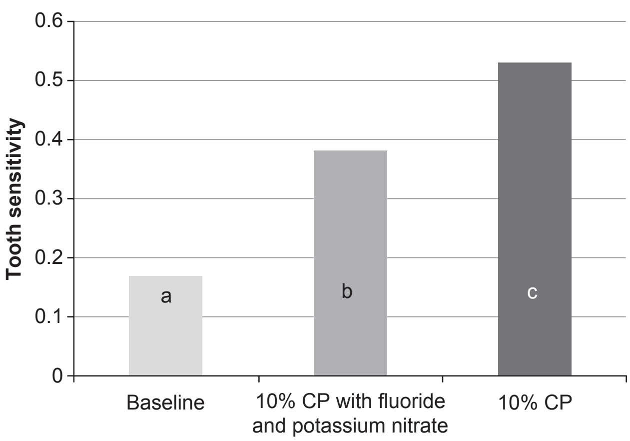

Fig. 1. Mean values of tooth sensitivity for both the tested products. Different letters indicate a statistically significant difference at $P < 0.05$. CP, carbamide peroxide.

Bleaching effect

Both groups showed comparable colour parameters at baseline and after treatment. L^* significantly increased while a^* and b^* decreased after bleaching ($P < 0.05$), with no significant difference between the two whitening systems (Table 1). ΔE was comparable between the two bleaching systems (Table 1).

Effect on enamel surface

The SEM analysis showed no morphological changes on the enamel surface after treatment with both bleaching agents (Figs 2a and b and 3a and b). Conversely, the positive control (phosphoric acid-etched enamel) showed clear morphological alterations (Fig. 4a and b).

Discussion

The results of this *in vivo* study indicate that dentist-supervised nightguard bleaching with both tested products (both containing 10% CP with or without fluoride and potassium nitrate, respectively) for 2 weeks (with an application time of at least 6 h) led to increased tooth sensitivity; however, the 10% carbamide peroxide gel with fluoride and potassium nitrate induced lower hypersensitivity than the product without desensitizing agents. In contrast, comparable results in terms of bleaching efficacy and absence of superficial morphological alterations were obtained with both bleaching agents. Thus, the tested hypothesis was partially rejected.

Increased sensitivity after bleaching confirms previous reports of tooth sensitivity as a recurring side effect of nightguard bleaching (5, 10, 34–36). Use of desensitizers during the bleaching treatment has been suggested; even if the desensitizing treatment does not reduce the incidence of tooth sensitivity, it is able to reduce its intensity (37, 38). Recently, the blending of desensitizing agents within bleaching products has been proposed by manufacturers to reduce tooth sensitivity consequent to bleaching procedures. There are two mechanisms of reducing tooth sensitivity: decreasing the excitability of the pulpal nerve fibres, inducing an anaesthetic effect (37), which is used by bleaching agents containing potassium nitrate (37, 39, 40), or reducing the dentinal fluid flow by blocking

Table 1. **Tooth colour parameters before and after treatment, expressed as mean (standard deviation)**

	10% carbamide peroxide with fluoride and potassium nitrate		10% carbamide peroxide without desensitizing agents	
	Baseline	After treatment	Baseline	After treatment
L^*	79.35 (2.12)^a	81.99 (1.61)^b	79.34 (1.95)^a	81.46 (2.49)^b
a^*	2.54 (1.07)^a	1.69 (0.59)^b	2.56 (0.58)^a	1.88 (0.50)^b
b^*	17.88 (2.29)^a	12.62 (1.79)^b	16.79 (1.92)^a	12.75 (1.87)^b
ΔE	6.19 (1.96)^a		4.89 (1.99)^a	

Different superscript letters in a single row indicate statistically significant differences ($P < 0.05$).

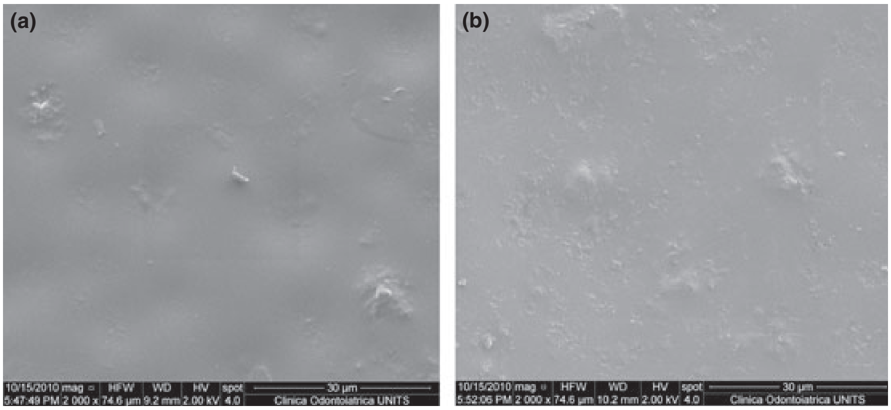

Fig. 2. Scanning electron microscope (SEM) images of the middle third of an upper incisor treated with 10% carbamide peroxide with fluoride and potassium nitrate at 2000×. (a) enamel before the application; (b) enamel after the application.

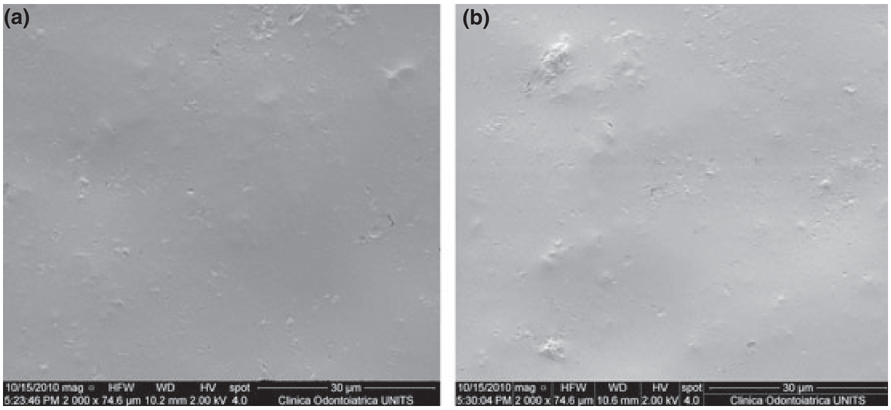

Fig. 3. Scanning electron microscope (SEM) images of the middle third of an upper incisor treated with 10% carbamide peroxide without desensitizing agents at 2000×. (a) enamel before the application; (b) enamel after the application.

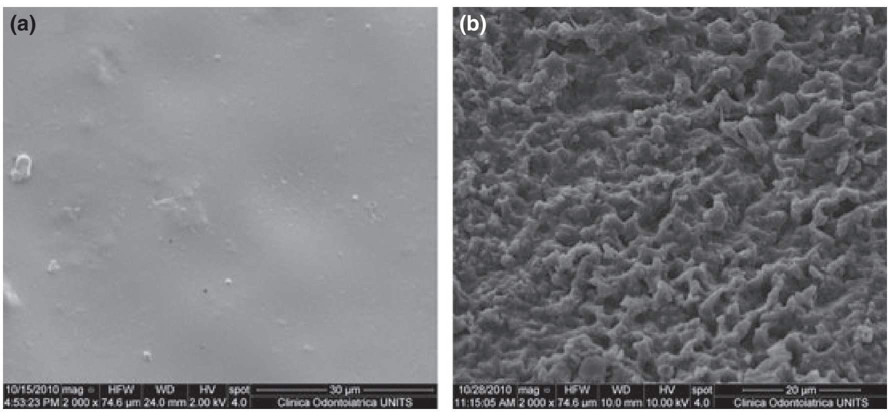

Fig. 4. The enamel etched with 37% orthophosphoric acid showed an altered surface in the scanning electron microscope (SEM) analysis (2000×). (a) unetched enamel; (b) etched enamel.

the tubule orifices. It has been supposed that products such as fluoride and amorphous calcium phosphate (ACP) can occlude the dentinal tubules due to the precipitation of calcium fluoride crystals or hydroxyapatite crystals able to settle on the tooth surface (38, 41–43). This study confirms that tooth sensitivity can be effectively decreased by addition of desensitizing agents, such as fluoride and potassium nitrate, to at-home bleaching products (44–47).

To evaluate the effectiveness of the bleaching treatment, many methods are available. The spectrophotometric analysis is fast and easy to perform and permits an objective colour evaluation using the CIE $L^*a^*b^*$ parameters. The $L^*a^*b^*$ three-dimensional colour space scale is the most frequently used index in colour science. Both products produced a similar and significant tooth colour lightening (expressed by L^*), confirming previous data (43, 48); the a^* and b^* values decreased significantly in both groups, indicating an increase in the green component and a reduction in yellowness accompanied by an increase in the blue tones, respectively. This aspect is remarkable, because the human eye has a preference for 'bluish' white (33). As the smallest colour difference perceivable by the human eye is approximately 0.5–1.0 ΔE units (33), the ΔE values obtained in this study suggested that the post-bleaching colour changes were clearly visible to the naked eye. However, tooth colour was evaluated only immediately after treatment, thus long-term assessment of bleaching effectiveness is necessary.

Previous studies showed that tooth bleaching causes enamel surface alterations due to the presence of reactive oxidative species and the pH of the products. However, the majority of the studies on enamel surface analysis were performed *in vitro* and frequently do not agree with *in vivo* observations (27). In this study, the presence of morphological alterations of enamel was assessed *in vivo*, using the replica technique (49). This method has the great advantage of evaluating the effects of the bleaching agents under intraoral conditions. The sensitivity of this method was validated using an etched positive control, in which the typical superficial alterations of etched enamel were clearly detected.

In this study, no difference in enamel morphology following treatment with the two bleaching systems was found, as has been reported previously (50–52): the tooth surfaces were clean and intact, with a morphology compatible with that of untreated enamel (Fig. 4a and b); no superficial changes compared to the normal morphology of surface enamel were detected, likely because the almost neutral pH of both 10% CP products (pH~6.5) (53–55) is not sufficient to cause enamel demineralization. These results do not exclude completely the potential alteration of the enamel surface or that the absence of changes in surface morphology can be related to the remineralizing effect of saliva (56, 57), as this study was performed *in vivo*.

Within the limitations of this study, it can be concluded that (i) the 10% carbamide peroxide gel with fluoride and potassium nitrate produced lower sensitivity levels than the 10% CP bleaching agent without desensitizing agents, (ii) the bleaching effectiveness of the two products was comparable and (iii) no alterations of the enamel surface were caused by either product.

Clinical relevance

Scientific rationale for the study

A possible drawback of tooth bleaching is tooth sensitivity; bleaching products with desensitizing agents are now commercialized to prevent tooth sensitivity. This study aimed to compare the effect of two 10% carbamide peroxide bleaching agents with or without fluoride and potassium nitrate on tooth sensitivity, colour, and enamel morphological changes.

Principal findings

Significantly lower tooth sensitivity was observed with the fluoride and potassium nitrate-containing bleaching agent. No differences in bleaching effectiveness or enamel alterations were found in both groups.

Practical implication

This study suggests that the addition of fluoride and potassium nitrate can reduce tooth sensitivity induced by bleaching.

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