Spectrophotometric and visual evaluation of vital tooth bleaching employing different carbamide peroxide concentrations

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ABSTRACT

Objective. The aim of the present study was to assess the hypothesis that the efficiency of vital tooth bleaching depends on the concentration of carbamide peroxide agents.

Methods. The front teeth of 30 subjects were bleached at home with 10%, 17% or 0% (control) carbamide peroxide for 1 week in a double-blind study design. Tooth shades were determined in the LCH color space employing a visual shade matching system and a spectrophotometer. Differences in lightness (∆L), chroma (∆C) and hue (∆H) were measured to assess the treatment process. After 2 weeks of no treatment, tooth shades were evaluated again to assess stability of the resultant shade.

Results. First-time changes of shade values could be observed after 3 days in the 17% group and after 7 days in the 10% group. After 1 week, in both the 17% group (∆L: 2.80, ∆C: −3.33, ∆H: 0.60) and the 10% group (∆L: 2.61, ∆C: −2.54, ∆H: 0.09), values for lightness and chroma were significantly different from the control (∆L: 0.13, ∆C: 0.14, ∆H: 0.21, p < 0.05) with no difference between the test groups (p > 0.05). Two weeks after treatment, a rebound of shade values could be observed in the test groups (p < 0.05).

Significance. The study indicates that higher concentration bleaching agents might whiten teeth faster with major changes in lightness and chroma. However, by bleaching daily for 1 week, similar effects can be achieved with both a high and a low concentration agent. After treatment, a regression of the resultant shade has to be expected.

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1. Introduction

Vital tooth bleaching is an increasingly requested dental treatment. Especially by whitening their front teeth, patients want to improve their esthetic appearance. In contrast to more aggressive methods like crowns or resin-bonded veneers, vital tooth bleaching is considered a more conservative approach to lightening teeth. Carbamide peroxide is a well-accepted agent for at-home bleaching supervised by a dentist [1,2]. Usually a gel, it is applied to the external surfaces of teeth with a customized tray. Bleaching occurs as unstable free radicals interact chemically with organic pigment molecules contained in dental hard tissues, reducing them to smaller, less pigmented molecules [3]. In the past, a 10% concentration of carbamide peroxide was considered as the standard [4,5]. In an attempt to increase the efficiency of the bleaching agents, higher concentrations were also used [6,7]. However, most studies on tooth whitening relied solely on a subjective color matching technique to evaluate the outcome of bleaching procedures [8–11] and only a few controlled clinical trials reported the effects of higher concentration agents. Therefore, the aim of the present study was to evaluate the efficiency of two different
concentrations of carbamide peroxide using both a subjective shade matching system and a spectrophotometric analysis in a double-blind study design. Also, any possible rebound effect after discontinuation of treatment should be assessed, regarding changes in lightness, chroma and hue in the LCH color space.

2. Materials and methods

Thirty patients, each of whom had no teeth discolored for extrinsic or intrinsic reasons, were treated in a double-blind study design. The Ethics Committee had been notified and patients had given their informed consent to their participation in the study. Calculus and stain were removed with an ultrasonic instrument (Sirona S, Siemens, Bensheim, Germany), a rubber cup and a polishing paste (Proxyl, Vivadent, Ellwangen, Germany) at least 2 weeks before the bleaching treatment phase of the study was initiated. During the same visit, alginate impressions were taken of the maxillary and mandibular arch of each patient. The oral and facial surfaces of the trays were trimmed just short of the gingival margins. The bleaching agents used in the study were fabricated using a double-blind process according to the manufacturer’s recommendations. The oral and facial surfaces of the trays were trimmed just short of the gingival margins.

Tooth shades of the upper and lower front teeth were determined in the LCH color space by an operator experiencing in color evaluation employing a visual shade matching system with all shades systematically placed at exactly \( \Delta E \) (Vitapan 3D, Vita Zahnfabrik, Bad Saeckingen, Germany). First, lightness of the teeth was assessed by selecting the closest match from one of five value groups. Second, chroma was assessed within that group from three choices. Third, hue was selected by determining if the tooth was more reddish or more yellowish than the shade sample selected. All subjective shade assessments were made under constant light conditions.

Additionally, tooth shades of the upper and lower front teeth were determined in the LCH color space using a spectrophotometer (SpectroShade™, MHT, Niederhasli, Switzerland), which allowed images to be taken that were uninfluenced by variables that could affect a visual determination, such as visual perception, office lighting or time of day. Values for lightness, chroma and hue were displayed by the personal computer of the spectrophotometer system. Tooth dehydration during the shade evaluation procedures was avoided by allowing the patients to close their mouth frequently throughout the shade matching process.

The bleaching agents used in the study were fabricated and analyzed by the manufacturer (Voco, Cuxhaven, Germany) to determine the exact percentage of carbamide peroxide. Unmarked syringes containing either a 0% (control), 10% or 17% concentrated gel were packed in equal treatment kits numbered consecutively, so that neither the operator nor the patient was aware of the concentration. After stratification of the patients by gender, age and baseline shade, these kits were assigned to the patients by a different operator who was aware of the peroxide concentrations but did not participate in the study otherwise. Subjects were instructed to wear the bleaching trays from 7 p.m. to 9 p.m. every day for 1 week starting on Monday. Tooth shades were assessed daily from Tuesday to Friday and on Monday of the next week, employing the visual shade matching system. At the end of the treatment phase on Monday an additional spectrophotometric shade analysis was performed (Fig. 1). During the following 2 weeks patients did not perform any bleaching procedure. Tooth shades were evaluated again with the visual shade matching system after 1 and after 2 weeks to assess any possible rebound effect following discontinuation of treatment. To avoid bias, all results were noted on separate forms by a second operator. Additionally, at the end of the second week another spectrophotometric analysis was performed.

For statistical analysis, normal distribution of the values was evaluated with the Shapiro–Wilk test. As both the values of the visual shade matching system and the spectrophotometer were normally distributed, analysis of variance (ANOVA) with subsequent comparison of mean values (Scheffé) was used to compare lightness, chroma and hue for the different carbamide peroxide concentrations over time. Changes in lightness, chroma and hue directly after bleaching and 2 weeks after treatment were analyzed using the Wilcoxon two-sample paired signed rank test. Differences were considered as statistically significant at \( p < 0.05 \).

3. Results

3.1. Visual shade matching system

First-time application of the bleaching gels did not result in any increase of lightness in either the control or the experimental groups \( (p > 0.05, \text{Table 1}) \). Hereupon, in the 17% per-
Table 1 – Visually assessed tooth lightness during the 1 week of bleaching and weekly after treatment depending on the concentrations of the bleaching agents

<table>
<thead>
<tr>
<th>Lightness [U]</th>
<th>0%</th>
<th>10%</th>
<th>17%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0%</td>
<td>2.8</td>
<td>2.9</td>
<td>3.0</td>
</tr>
<tr>
<td>10%</td>
<td>2.6</td>
<td>2.5</td>
<td>2.3</td>
</tr>
<tr>
<td>17%</td>
<td>2.5</td>
<td>2.3</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>S.D.</strong></td>
<td>0.4</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>p (0%–10%)</strong></td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>p (10%–17%)</strong></td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>p (0%–17%)</strong></td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

Differences between the groups were evaluated using ANOVA with subsequent Scheffé test and considered as statistically significant at \( p < 0.05 \).

From the seventh day values in the 10% peroxide group and from the third day values in the 17% peroxide group differed from the control group (\( p < 0.05 \)). After 7 days of treatment, whitening of the teeth in the 17% peroxide group (lightness: 1.8 ± 0.3 U) was no more efficient than in the 10% group (lightness: 2.0 ± 0.3 U) (\( p > 0.05 \)). Both values were statistically different from lightness in the control group (2.5 ± 0.3 U). Two weeks after bleaching, lightness in both test groups decreased, but was still higher than in the control group (\( p < 0.05 \)). Values for chroma tended to decrease in the test groups with no statistical difference to the control group (\( p > 0.05 \)), and values for hue did not change (\( p > 0.05 \)).

3.2. Spectrophotometric analysis

Overall, directly after bleaching for 1 week, in both test groups with either 17% (\( \Delta L: 2.80, \Delta a: -3.33, \Delta h: 0.60 \)) or 10% peroxide (\( \Delta L: 2.61, \Delta a: -2.54, \Delta h: 0.09 \)) a significant increase of lightness, decrease of chroma and slight increase in hue could be observed, as compared to the control group (\( \Delta L: 0.13, \Delta a: -0.14, \Delta h: 0.21, p < 0.05 \), Fig. 2). There was no statistical difference between the values in the 17% and the 10% groups (\( p > 0.05 \)). After 2 weeks, a statistically significant decrease in the values for lightness and chroma could be observed in the test groups (\( p < 0.05 \)) with no change of hue (\( p > 0.05 \)). Since there was a similar decrease in the 17% group (\( \Delta L: 1.98, \Delta a: -2.35, \Delta h: 0.47 \)) and in the 10% group (\( \Delta L: 0.13, \Delta a: -0.14, \Delta h: 0.21 \)), final values did not differ (\( p > 0.05 \)). Regarding the different types of teeth included in the study, major changes of shade values could be found for canines (Fig. 3). Changes of lightness, chroma and hue were statistically different from those observed for incisors (\( p < 0.05 \)).

4. Discussion

Using the same parameters as of the spectrophotometer to describe the tooth shade in the LCH color space, the visual shade matching system employed in the present study and the spectrophotometer complemented one another. The visual matching system allowed the daily effects of the whitening procedures to be noticed, and the spectrophotometer values verified these effects at intervals of 1 and 2 weeks. Employing this study design, the major hypothesis that the efficiency of vital tooth bleaching does depend on the concentration of carbamide peroxide agents could only be verified to some extent. Even though whitening of the teeth in the 17% per-
oxide group could be observed earlier than in the 10% group, after 1 week, shade values assessed both with visual shade matching and the spectrophotometer did not differ among the groups. This result raises the question as to whether highly concentrated agents are necessary for vital tooth bleaching. It is widely accepted that tooth sensitivity is a common side-effect of external tooth bleaching [12]. This sensitivity normally persists for up to 4 days after cessation of the treatment [13]. However, a longer duration of sensitivity of up to 39 days has also been reported [14,15]. The mechanisms that cause discomfort have not yet been fully established, but they might be associated with peroxide penetration of enamel and dentin [16], reaching even the pulp chamber [17]. The amount of peroxide in the pulp chamber is related to the concentration of the bleaching agent [18]. As the present study could demonstrate that the whitening effect of either a 10% or a 17% agent is not different after 1 week, a low concentrated bleaching gel seems to be more advisable to prevent tooth sensitivity.

Reviewing biological aspects, the recommendation is to avoid the use of concentrations higher than 10% carbamide peroxide for external vital bleaching [19]. Furthermore, evaluating the efficiency of a tooth whitening gel containing 25% carbamide peroxide and a gel containing 8.7% hydrogen peroxide, no statistical difference in tooth whitening could be observed [20]. Another study compared a tooth whitener containing 5% and one containing 10% carbamide peroxide. Assessing the efficiency of bleaching over a period of 1 week the authors suggested that the whitening gels were clinically equivalent [21]. Using a value-oriented shade guide, there was no statistical difference between the outcome of a 10% and a 15% carbamide peroxide containing gel after 1 week's application [6].

In the present study, bleaching trays were constructed with facial reservoirs for the whitening agent. One could argue that the thickness of these reservoirs might have influenced the effectiveness of the bleaching gels. Assessing the impact of reservoirs on tooth whitening, it could be demonstrated by a colorimeter that teeth treated with trays without reservoirs were significantly darker than teeth lightened with reservoirs [22]. However, the difference was below the threshold of visual differentiation. The reservoirs of bleaching trays in the present study did not differ to a great extent. Thus, the size of the facial reservoirs might have had only a minor impact on the present results.

Assessment of tooth color can be affected by the surrounding light [23]. In the present study, it was not important to
judge the color shade which matches the tooth in daylight but
to assess color changes caused by the bleaching procedure.
For this reason, visual shade matching took place under con-
stant light conditions in a room only illuminated by artificial
light. Spectrophotometric shade analysis was not affected by
the surrounding light, as it was possible to isolate a tooth with
the optical mouthpiece of the optic handpiece. Likewise, the
spectrophotometric evaluation was not performed to assess
the exact tooth color in daylight but focused on assessing color
changes over time.

Employing subjective and objective methods for assessing
tooth color variations, the present study indicates that both
a 10% or a 17% concentrated bleaching gel might result in
similar tooth whitening after 1 week. The higher concentra-
tion bleaching agent is capable of whitening teeth faster with
major changes in lightness and chroma. However, taking into
account the biological aspects, it is advisable to use the low
concentration agent to avoid side effects such as tooth sensi-
tivity.

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