

Volume 16, Number 4, Winter 2009

# CURRENT PRACTICE

## WHITENING

*Guest Editor*

Van Haywood, DMD

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# CONTENTS

## Volume 16(4): Winter 2009

*Clinical Evaluation of In-office Dental Bleaching Treatments With and Without the Use of Light-activation Sources*

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*A Clinical Evaluation of Two In-office Bleaching Regimens With and Without Tray Bleaching*

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*Review of the Effectiveness of Various Tooth Whitening Systems*

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## Course Objectives

The objective of this issue of *Current Practice* is to bring the reader a concise overview of the latest science behind tooth bleaching. After reading the articles selected, the reader will be able to identify preferences in light activation sources and choose the most effective methods for in-office and at-home systems as well as compare and contrast the differences between the options available.

In addition the reader will be able to better discuss with patients, the indications and contraindications for bleaching and the rationale for which system is the best for individual patient need based upon patient expectations and preventing post-treatment sensitivity. The reader will be able to list the recommended desensitizing products that work well with bleaching procedures.

Covered in this issue is a definitive overview of the research methods used to scientifically evaluate the various bleaching systems on the market and thus, the reader will be able to discuss the scientific rationale for concentration of bleaching agent used over specific durations of time and their long term effectiveness.

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## Answers: Vol 16(3): Fall 2009

The Major Part of Dentistry You May be Neglecting

1. D 2. D 3. B 4. A 5. D

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1. B 2. A 3. A 4. B 5. A 6. A 7. B 8. A 9. A 10. A

An Evidence-based Assessment of Occlusal Adjustment as a Treatment for Temporomandibular Disorders

1. C 2. D 3. D 4. A 5. C

The Premise of Comprehensive Dentistry

1. E 2. F 3. A 4. A,B,C,D

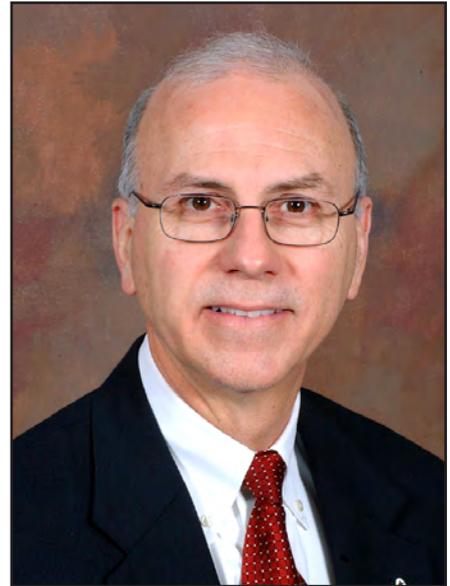
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## IN-OFFICE BLEACHING: LIGHTS, APPLICATIONS, AND OUTCOMES



*Dr. Haywood*

In-office bleaching dates back to 1848 but has enjoyed a tremendous recent resurgence of usage since the 1990s after tray bleaching popularized the bleaching options. With this occurrence, there are several questions about in-office bleaching that continue to surface. First, does the light make a difference in the final outcome of in-office bleaching? Second, does one in-office bleaching yield the same results as tray bleaching? And, finally, would a combination of in-office and tray bleaching yield a better final outcome? The purpose of this article is to explore these questions based on the current literature.

Lights have been associated with in-office bleaching since the 1800s. That association was a logical development in the early days of bleaching since we know that heat and light speed up a chemical reaction. Many different techniques and materials were tried in the late 1800s to lighten first non-vital and then vital teeth. The traditional technique for in-office bleaching as we recognize it today was formally described in the early 1900s in *Dental Cosmos*<sup>1,2</sup>, which was one of the precursors to the *Journal of the American Dental Association*. The clinical observation was that the teeth appeared lighter with the use of the light immediately after treatment. However,

their clinical experience was also that it took one to four visits to obtain patient satisfaction.

The in-office bleaching technique was popular in the late 1800s and early 1900s. During this time, there were many articles about bleaching and esthetics appearing in the dental journals, and discussions about the chemistry of bleaching at conventions and dental meetings. However, most of the bleaching literature disappeared from journals at the end of the early 1900s, possibly due to World War I, the Great Depression, and World War II. Bleaching resurfaced in the late 1950s in response to fluorosis problems in certain parts of the country coupled with the more affluent post-World War II society, which was interested in esthetics. When acid-etching techniques entered the dental world in the 1970s, that step was also included in the in-office bleaching process, again because, clinically, the tooth appeared lighter immediately after treatment.

Recently, a call for evidence-based dentistry has caused the profession to re-examine some of the traditional bleaching treatment options and concepts. More education and insights into the scientific method, with the use of control and treatment groups, have uncovered new insights into the bleaching process.

Soon evidence about the permeability of the tooth to peroxide and other low-molecular-weight materials emerged. Studies showed that peroxide could easily pass through intact enamel and dentin to the pulp in 5–15 minutes. Hence, there was no need to acid-etch or condition the tooth surface to make the surface more bleachable. In 1991, Hall demonstrated that acid-etching did not improve the efficacy of bleaching, and that the etching step should be dropped from the in-office procedure.<sup>3</sup> Typically, etching only gives the appearance of whitening due to the frosty surface of the enamel changing the optical properties.

The question of how effective the lights are with in-office bleaching remained unanswered, partially due to a general lack of funding for research on esthetics. Research in 2000 demonstrated that the application of a rubber dam alone would cause a lightening of the tooth for a  $\Delta E$  of 6.26, which is approximately six to 12 shade changes on the Vita Classic shade guide, depending on where the tooth colour measurement begins. This rubber dam lightening phenomenon is often seen in dental student clinics and may be termed “rubber dam bleaching.” When new young dental students are placing their first composite restoration, the patient remains under the rubber dam for a long period of time. The dehydration effect of isolation on teeth is demonstrated when a rubber dam is used to isolate the teeth for an hour or more. The tooth dehydrates under these conditions, which then results in six to 12 shade changes on a Vita Shade guide, without any actual bleaching having occurred. The “lightened” teeth return to a normal colour after a period of hours or days—hence, the admonition for dentists to always select a composite shade prior to rubber dam isolation.

Since it also has been determined that teeth do not all bleach at the same rate or to the same extent, what was needed to help answer these in-office bleaching and light questions was either an extremely large number of patients or a “split-arch” design on each patient. In the split-arch study design, one side of the arch serves as the control and the other receives the treatment. This approach allows accurate testing of the technique with far fewer subjects than does the traditional large clinical trial, and it tests similar teeth with the different treatment conditions. This design was first demonstrated in print by Hein and colleagues in 2003 in the Clinical Research Associates

(CRA) group.<sup>4</sup> His group tested one side of the arch with light-activated bleaching and the other side without light activation. He found no difference in the efficacy of bleaching.

Later, an article appeared in *Journal of the American Dental Association* that implicated that the light makes a difference.<sup>5,6</sup> However, the colour was measured immediately after removal of the rubber dam, which introduces the confounding bleaching effect due to isolation dehydration. Most other bleaching studies have shown that the proper time to measure the colour change from bleaching is at least 2 weeks after the termination of bleaching treatment and may be as long as 6 weeks with higher concentrations of materials. This delay in colour-measurement avoids the dehydration effect of the isolation technique, and it allows the oxygen generated from bleaching to dissipate from the tooth. Additional oxygen in the tooth from the bleaching process seems to affect both the optical qualities and the bond strengths to the tooth by approximately 25% immediately after bleaching. Although the particular company cited in the article has restricted research on the current product, CRA had tested the original product, which consisted of a 50% hydrogen peroxide activated by a laser, and found that the laser did not make a difference in bleaching efficacy.<sup>7</sup>

In late 2005 and early 2006, several scientific articles appeared that finally clarified what clinicians seem to report about in-office bleaching and lights. In January 2006, Kugel and colleagues compared a light-activated in-office bleaching material with a chemically activated material that did not involve the use of a light. They used a split-arch design so that each mouth served as its own control.<sup>8</sup> They found that immediately after bleaching, the light-activated side appeared lighter. However, in 2-week post-treatment evaluations, there was no difference between the light-activated side and the non-light-activated side. The investigators observed that the immediate change in the light-activated material seemed to be related to the dehydration effect of the isolation and heat of the light rather than any improvement in bleaching efficacy.

Another study in February of 2006 demonstrated that it takes more than one visit with in-office light-activated bleaching to achieve patient satisfaction.<sup>9</sup> In this study, the range was one to four visits; even then, some people were not satisfied with the results.

Several of the patients chose to continue bleaching with at-home tray bleaching rather than have an additional in-office treatment. Only 26% of the patients were satisfied with one in-office bleaching treatment, and these were generally patients with an initial shade of A2 or lighter on a Vita Classic shade guide.

Patients often want one in-office treatment to take the place of using an at-home tray treatment. However, clinical evidence from the past 100 years indicates what recent research has confirmed—the range of treatment visits for maximum lightening with in-office bleaching is one to four applications, and it depends on the individual patient tooth colour and response rate of that tooth, rather than the concentration or technique of the bleaching material. Bleaching is time and concentration dependent to a certain extent, but the main limiting factor is the rate of colour change the tooth can accomplish.

A CRA survey in 2005 compared the usage of at-home tray bleaching with in-office bleaching, and it asked for reasons why the dentists use the light.<sup>10</sup> Some dentists stated that they use the light because it came with the system, some use the light because patients ask for it, and some use the light because it is good for marketing.

In the journal *Operative Dentistry*, Auschill and colleagues made a comparison among the three classes of bleaching (in-office, tray bleaching, and over-the-counter [OTC] strips).<sup>11</sup> To achieve a six-shade change, this group concluded that 7 days of 10% carbamide peroxide in a custom-fitted tray would be roughly equivalent to three in-office bleaching treatments or 16 days of a popular OTC bleaching strip.

In a 2007 *Operative Dentistry* article, a number of different in-office light-activated products were tested.<sup>12</sup> As with other reports, there was an immediate whitening of a  $\Delta E$  of 6 at week 1, followed by a sudden drop by week 2 to a level of approximately 2  $\Delta E$ . Although the sample size was small, the pattern among all the products was very similar—a sudden spike in the colour followed by a significant relapse. For most products, the relapse is to a colour lighter than the original, but the colour change does not remain at the immediate post-bleaching level.

The original instructions of a popular light-activated in-office product used in the television program *Extreme Makeover* actually recommends

following the one in-office treatment with at-home tray treatment to complete the bleaching process. What this in-office–tray approach accomplishes is to start the whitening process with a high concentration of hydrogen peroxide as well as create the illusion of whitening from the dehydration with one in-office treatment, and then—before the colour relapse occurs as described above—use the tray system at home to bring the teeth to the desired whitening level as they rehydrate.

For many years, it was thought that some form of light would make the whitening process work more quickly because, from a chemistry standpoint, heat and light speed up a chemical reaction. What we are now learning is that the tooth has a finite limit on how fast it will change colour and how white it will become that is specific to each individual. Once the limit for each particular person's teeth is reached, it apparently does not matter what else is attempted to boost the bleaching, the tooth colour will not change any further. All other “whitening effects” at that point are related to dehydration. Just as we have different, genetically determined hair and eye colours, we apparently all have different maximum tooth colours and different rates of change. That is why some people can tray-whiten their teeth in 3 nights, whereas for others it takes 6 weeks; and why some people can get successful results with one in-office treatment, whereas others need multiple visits. Whitening is more tooth specific than it is product or technique specific.

In-office whitening will continue to be a treatment option in the dental bleaching armamentarium. Not every person can or wants to wear the tray delivery products. Dentists should inform their patients that, although one in-office treatment will lighten their teeth, patients may need multiple treatments to reach their maximum or desired whiteness. Patients need to be prepared financially and emotionally for the possibility of additional treatments since we are unable to predict either the rate or maximum colour change of a tooth prior to bleaching. Lights may have their place to encourage subsequent home compliance by boosting the initial perception that whitening is occurring while waiting for the tray bleaching technique to finally whiten the teeth. However, care should be used in expecting any product or system to overcome the limitations imposed by a patient's genetic coloration and a tooth's rate of change.

After reviewing these cited articles and others written since,<sup>13-15</sup> the following conclusions concerning the original questions may be drawn.

1. The light does not make a difference in the final outcome of in-office bleaching; instead, it primarily contributes to the illusion of whitening through dehydration in the first week. This occurrence may encourage compliance for the patient to continue with tray bleaching or to return for subsequent in-office treatments. There is a significant relapse in colour after in-office bleaching.
2. One in-office bleaching does not yield the same results as tray bleaching. Rather, multiple treatments may be needed based on the initial discoloration, with three visits being the average. Patients must be willing to have and pay for multiple in-office treatments to reach their maximum whitening. Sensitivity is greater with in-office treatments than with tray bleaching, especially with longer in-office treatments, so steps must be taken to minimize or relieve sensitivity.
3. A combination of in-office and tray bleaching yields a better final outcome than a single in-office treatment. However, the final bleaching result is the same regardless of the treatment used (tray, in-office, OTC) if there are enough bleaching treatments with a reputable product over a long enough time. Hence, the total fee for both procedures may not justify the outcome, so the cost-benefit ratio of combining techniques must be presented to the patient. Compliance may be helped by the immediate peroxide/dehydration of an in-office treatment, but the final outcome is still dependent on the tooth's response to peroxide when enough proper treatments are applied.

A further in-depth reading of the attached articles along with the questions will further elaborate on the current insights concerning in-office bleaching.

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# Continuing Dental Education Questions

## Clinical Evaluation of In-office Dental Bleaching Treatments With and Without the Use of Light-activation Sources

*FC Marson, LG Sensi, LCC Vieira, E Araújo*

1. What is the total bleaching time for each in-office treatment?
  - a. 15 minutes
  - b. 45 minutes
  - c. 90 minutes
  - d. 120 minutes
  
2. What percentage of the patients had tooth sensitivity?
  - a. 24%
  - b. 52%
  - c. 63%
  - d. 92%
  
3. Which light source was the most successful in bleaching?
  - a. Halogen
  - b. LED
  - c. Laser
  - d. All were equal
  
4. How did the outcome of “light” bleaching compare to the “no light” bleaching?
  - a. Same outcome between bleaching with and without a light
  - b. “Light” bleaching was better than “no light” bleaching
  - c. “Light” bleaching was not as good as “no light” bleaching
  
5. What did the authors recommend for reducing sensitivity?
  - a. Schedule bleaching appointments one week apart
  - b. Apply potassium nitrate for 10 minutes prior to bleaching
  - c. Both a and b
  - d. Neither a nor b
  
6. Sensitivity during in-office bleaching was attributed to:
  - a. High concentration of peroxide
  - b. Long treatment times
  - c. Heat or light
  - d. All of the above
  - e. Both a and c

7. What did the authors recommend for maximum whitening from their study?
  - a. Multiple in-office treatments
  - b. Use of in-office followed by tray bleaching
  - c. Both a and b
  - d. Neither a nor b, since one application achieved maximum whitening
  
8. How did the authors record color changes?
  - a. With 1 method using Vita Shade guide
  - b. With 1 method using Easy Shade guide
  - c. With 2 methods using Vita and Easy Shade
  
9. How long before the sensitivity abated?
  - a. 5 minutes
  - b. 1 hour
  - c. 24 hours
  - d. 1 week
  
10. Was sensitivity more or less after the second session was completed?
  - a. More
  - b. Less
  - c. Same
  
11. Which provided the most long term stability?
  - a. Light bleaching
  - b. No light bleaching
  - c. Both were the same

## **A Clinical Evaluation of Two In-office Bleaching Regimens With and Without Tray Bleaching**

*BA Matis, MA Cochran, G Wang, GJ Eckert*

1. In this study, what different types of in-office treatments were evaluated?
  - a. 36% hydrogen peroxide applied 1 time for 40 minutes
  - b. 36% hydrogen peroxide applied 3 times for 15 minutes
  - c. Both a and b
  - d. Neither a nor b

- 
2. In order to bleach teeth, hydrogen peroxide passes easily through...
    - a. The enamel
    - b. The dentin
    - c. Neither a nor b
    - d. Both a and b
  
  3. In this study, the subjects received a prophylaxis at what time interval prior to bleaching?
    - a. Immediately prior to bleaching
    - b. At least one week prior to bleaching
    - c. At least two months prior to bleaching
    - d. They did not receive a prophylaxis since the bleaching will remove stains
  
  4. What type of tray design was used with the in-office bleaching?
    - a. Full arch tray
    - b. Half-arch tray
    - c. Tray on opposite arch which was not bleached with in-office bleaching
  
  5. How long and at what concentration was the tray bleaching used in conjunction with the in-office bleaching procedures?
    - a. 15% carbamide peroxide used for 14 days
    - b. 10% carbamide peroxide used for 7 days
    - c. 15% carbamide peroxide used for 7 days
    - d. 10% carbamide peroxide used for 14 days
  
  6. What effective concentration of hydrogen peroxide would 10% carbamide peroxide yield?
    - a. 10%
    - b. 3.4%
    - c. 15%
    - d. 1%
  
  7. Which in-office bleaching technique used alone had the least gingival or tooth sensitivity?
    - a. 36% hydrogen peroxide applied 1 time for 40 minutes
    - b. 36% hydrogen peroxide applied 3 times for 15 minutes
    - c. Both were the same
  
  8. Which in-office bleaching technique used alone had the best whitening?
    - a. 36% hydrogen peroxide applied 1 time for 40 minutes
    - b. 36% hydrogen peroxide applied 3 times for 15 minutes
    - c. Both were the same

9. Which overall bleaching technique had the best whitening?
  - a. 36% hydrogen peroxide applied 1 time for 40 minutes
  - b. 36% hydrogen peroxide applied 3 times for 15 minutes
  - c. 36% hydrogen peroxide followed by tray bleaching
10. What material was to be applied for sensitivity?
  - a. Fluoride
  - b. Potassium nitrate
  - c. Sodium chloride
  - d. Amorphous calcium phosphate

## Review of the Effectiveness of Various Tooth Whitening Systems

*BA Matis, MA Cochran, G Eckert*

1. Which bleaching was determined to be the best?
  - a. In-office
  - b. Day time tray wear
  - c. Night time tray wear
  - d. Over the counter
2. How did the color change immediately post-bleaching compare to the color at 10 weeks?
  - a. Less color change at 10 weeks than immediately after bleaching with the in-office bleaching
  - b. Less color change at 10 weeks than immediately after bleaching with the tray bleaching
  - c. Both techniques remained the same at 10 weeks immediately after bleaching.
  - d. Both techniques reduced at 10 weeks as compared to immediately after bleaching
3. At the time of this publication (2009), how many dental bleaching products had been awarded the ADA Seal of Acceptance?
  - a. 1
  - b. 2
  - c. 5
  - d. 10

- 
4. Which study design do the authors state is best for evaluating bleaching techniques?
    - a. Split arch or half mouth
    - b. Multi-cells of subjects
    - c. Multi-centers of subjects
    - d. Cross-over design
  
  5. When using Delta E color measurements, what is the difference in Delta E units that can first be seen by most clinicians?
    - a. .5-1 Delta E unit
    - b. 2-4 Delta E units
    - c. 6-10 Delta E units
  
  6. Which shade guide was used in this study?
    - a. Vita Classic
    - b. Trubyte Bioform
    - c. Vita 3-D Master
  
  7. In compiling these various bleaching studies, what was the common time frame chosen for follow-up comparisons?
    - a. 2 weeks
    - b. 6 weeks
    - c. 10 weeks
    - d. 21 weeks
  
  8. What do these authors suggest is the minimal time to wait for the color to stabilize?
    - a. 1 day
    - b. 1 week
    - c. 2 weeks
    - d. 4 weeks
    - e. 10 weeks
  
  9. At what time interval did one in-office treatment equal the results of over the counter bleaching?
    - a. 2 weeks
    - b. 6 weeks
    - c. Never, in-office was always better than over the counter
  
  10. What do the authors suggest to maximize the results from in-office bleaching?
    - a. Follow-up one in-office bleaching with tray bleaching
    - b. Nothing, since one in-office bleaching obtains the maximum color change

# Clinical Evaluation of In-office Dental Bleaching Treatments With and Without the Use of Light-activation Sources

FC Marson • LG Sensi  
LCC Vieira • E Araújo

## Clinical Relevance

The use of light-activation sources did not affect the outcome of in-office bleaching with 35% hydrogen peroxide.

## SUMMARY

**This study clinically evaluated the alteration of color, color stability, dental sensitivity and gingival irritation on patients undergoing dental bleaching using varying bleaching methods and light-activation sources. According to pre-established criteria, 40 patients were selected and ran-**

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DOI: 10.2341/07-57

**domly divided into four groups (n=10): Group 1-35% Hydrogen Peroxide (HP); Group 2-35% HP plus Halogen Curing Light XL 3000 (3M/ESPE); Group 3-35% HP plus Demetron LED (Kerr) and Group 4-35% HP plus LED/LASER (Bio-art). For all groups, there were two sessions of bleaching with 35% HP, with a one week break between sessions. At each bleaching session, three applications of the bleaching gel were used. Two methods of shade evaluation were performed before and after the first week, second week, first month and after six months of the bleaching treatment. These methods were VITA Easyshade Spectrophotometer and Vita Classical Shade Guide. Statistical analysis using ANOVA demonstrated equality between the participating groups when evaluating the group and time variables. The In-Office dental bleaching treatments of vital teeth with 35% HP did not prove to be more effective when light sources were used. There was no difference in color stability between groups until the sixth month of evaluation.**

## INTRODUCTION

Tooth whitening is one of the most requested cosmetic dental procedures asked for by patients who want a more pleasing smile. This procedure consists of carbamide or hydrogen peroxide gel applications that can be done in-office or by the patient (at-home/overnight bleaching system).<sup>1</sup>

Even though the at-home bleaching system is the most frequently recommended treatment for vital teeth, some patients do not adapt to the technique, because they prefer not to use a bleaching tray or do not like to wait two to three weeks to see the results of their treatment. These patients might request a method that produces more immediate results, the in-office bleaching treatment.<sup>2</sup>

Since the introduction of in-office bleaching treatments, the use of curing lights (including halogen curing lights, plasma arches, LED, LED plus lasers, lasers) has been recommended to accelerate the action of the bleaching gel. In the past, the clinical results obtained with the use of these lights were poor, showing an increase in tooth sensitivity and reduced long-term color stability, especially when the treatment was done in one appointment. Recent developments in in-office bleaching systems that use a chemical catalyst combined with light-cured block-out materials and compounds have resulted in decreased tooth sensitivity and enhanced treatment and have demonstrated improved results.<sup>3</sup>

Despite the fact that many curing lights have been introduced into the dental market for the purpose of accelerating in-office bleaching treatments, no concrete scientific study has proven their effectiveness.<sup>4-6</sup>

This research clinically evaluated whether using different light-activation sources would affect the outcome of in-office bleaching treatments completed with a 35% hydrogen peroxide gel.

## METHODS AND MATERIALS

Based on pre-established criteria, 40 patients were selected for this study. They:

- were between the ages of 18 and 28;
- had caries-free vital anterior teeth without restorations;
- had good oral hygiene;
- were free of periodontal disease and gingival irritation;
- were non-smokers and
- were free of cervical lesions and any painful symptoms.

Patients were excluded from the study if they:

- were pregnant or nursing;
- had severely stained teeth (tetracycline stains, fluorosis, endodontic treatment) and
- had previously undergone tooth-whitening procedures.

After the dental screenings and case history check-ups, the patients were informed of the treatment procedures, including the pros and cons of in-office bleaching and the possible side effects (sensitivity and gingival irritations). The subjects gave their informed consent before the study began. Tooth sensitivity was verified with a light air jet over the labial surface of the teeth, with the degree of sensitivity recorded using the following criteria: 1-none, 2-slight, 3-moderate and 4-severe.

During bleaching treatments, the degree of gingival irritation was measured using the Loe Gingival Method<sup>7</sup> and was recorded using the following criteria: 1-none, 2-slight gingival irritation, 3-moderate gingival irritation and 4-severe gingival irritation.

Shade evaluation was recorded before and after the bleaching treatment using two methods of evaluation (shade guide and spectrophotometer) (Table 1).

Table 1: *Shade Evaluation Methods*

Shade Evaluation Method	Material Used
Color Scale	Vita Classical Shade Guide
Spectrophotometer	VITA Easyshade, (Vident, Brea, CA, USA)

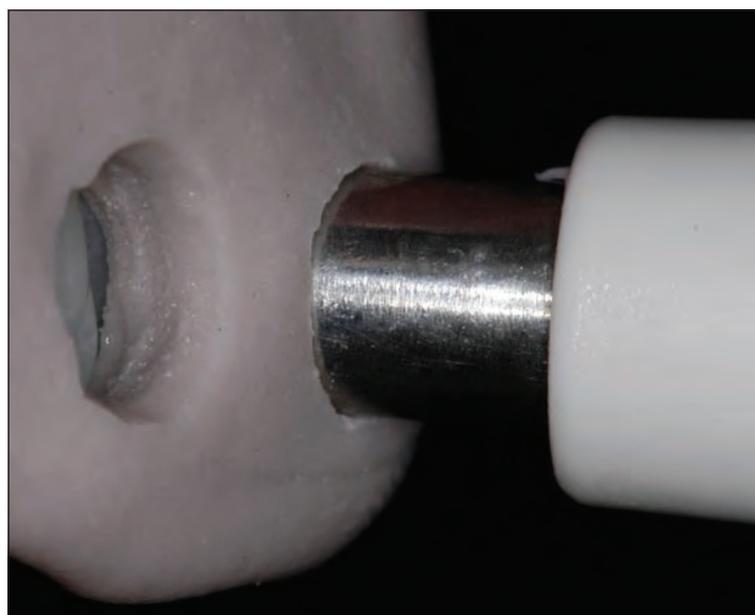


Figure 1: *Silicone Guide positioned over the labial surface of teeth with the tip of the device positioned for color measurement.*

Before beginning the bleaching treatment, the shade of the upper anterior incisors (canine to canine) of all 40 patients was recorded by two trained volunteers, using the Vita Classic Scale (Vita, Zahnfabrik, Sackingen, Germany).

Prior to the spectrophotometer measurement, an impression of the maxillary arch was made using Zetalabor dense silicone paste (Zhermarck, Italy). The impression was extended to the upper canine and served as a standard color measurement guide for the spectrophotometer. A window was created on the labial surface of the molded silicone guide for each dental component to be evaluated (Figure 1). The window was made using a metallic device with well-formed borders, 3 mm in radius. The measurement was done on all 40 patients using Vita Easyshade (Easyshade, Vident, Brea, CA, USA) (IE) before and after the first week, second week, first month and at sixth months following treatment. The shade was determined using the parameters of the Easyshade device where it indicated the following values: L\*, (c\*) and (h\*), in which L\* indicates luminosity, (c\*) value and (h\*) chroma. In order to make an easy comparison with other studies, these values were converted to the CIE-Lab system, (L\*, a\* and b\*), wherein L\* represents the value from 0 (black) to 100 (white) and a\* and b\* represent the shade, where a\* is the measurement along the red-green axis and b\* is the measurement along the yellow-blue axis. This system was defined by the International Commission on Illumination in 1967<sup>8</sup> and is referred to as CIELab. The color comparison before and after treatment is given by the differences between the two colors ( $\Delta E$ ), which is calculated using the formula:  $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$  (Commission Internationale de L'Eclairage, 1978).<sup>9</sup>

A 35% hydrogen peroxide (HP) bleaching agent was used for this study (Whiteness HP MAXX-FGM, Joinville, Brazil). In conjunction with the bleaching gel, a halogen curing light XL3000 (3M/ESPE), Demetron LED (Kerr Dental) and LED/Laser Biolux (BioArt) were used to activate the gel (Table 2).

The subjects were randomly divided into four groups (n=10) as shown in Table 3.

The bleaching treatment was the same for all four groups (G1, G2, G3, G4) except for altering the activation method of the bleaching agent. Before the vital teeth bleaching treatment, the gingival tissue was isolated using a light-cured resin dam (Top Dam, FGM,

Table 2: Equipment Used for Bleaching Gel Activation

Equipment	Type of Light	Wave Length	Manufacturer
Curing Light XL3000	Halogen Light	400 to 500 nm	3M/ESPE
Demetron	LED	450 to 500 nm	Kerr
Biolux	LED Laser	470 nm	BioArt

Table 3: Group Divisions

Group	N	Bleaching Treatment	Type of Photo Activation
1	10	35% HP	none
2	10	35% HP	Halogen Light
3	10	35% HP	LED
4	10	35% HP	LED/Laser



Figure 2: Gingival isolation using light-cured gingival dam (FGM). This dam is polymerized, so that it becomes rigid and protects the gingiva from the bleaching gel.



Figure 3: Application of the 35% HP bleaching gel (Whiteness MAXX, FGM).

Joinville, Brazil) to prevent the bleaching gel from contacting the gingival tissue (Figure 2).

To aid in the bleaching process, a labial retractor, plastic suction cup with high suction power and protection glasses were used. Whiteness HP MAXX (FGM, 35% HP) was used. This bleaching gel comes in two bottles, one containing hydrogen peroxide and the other the thickening agents. The manufacturer's instructions for



Figure 4: Patients were submitted to two sessions of bleaching, with three applications of bleaching gel in each session.

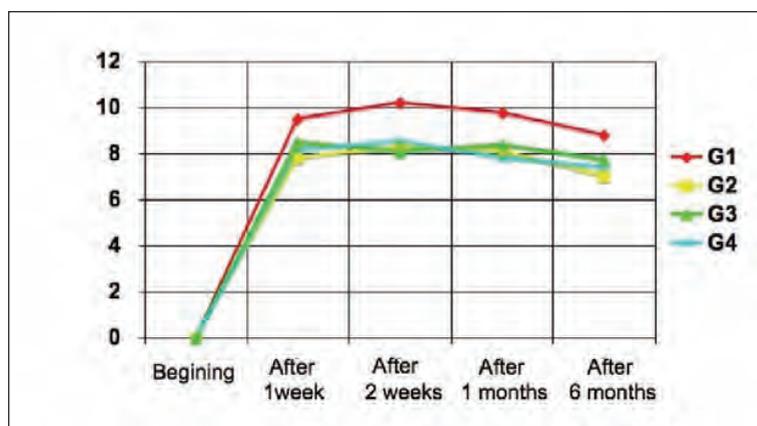


Figure 5:  $\Delta E$  in relation to time and instrumental evaluation.

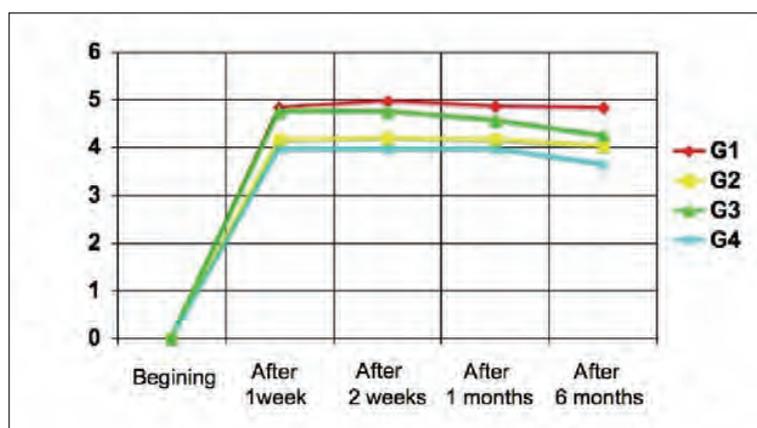


Figure 6: Evaluation using the color scale.

handling and applying were followed by mixing the peroxide and thickening agents using the proportion three drops of peroxide to one drop of the thickening agents. The mixture was blended using a circular motion until the gel formed and was then applied to the labial surface of the teeth to be bleached (Figures 3 and 4). To

bleach one arch, approximately 12 drops of peroxide to four drops of thickening agents was required.

In groups G2, G3 and G4, light curing was used at a distance of 1 cm from the bleaching gel, while G1 did not use any activator sources. All groups were submitted to two sessions of bleaching with 35% HP, with three applications of the bleaching gel at each session. Each bleach application lasted for 15 minutes, totaling 45 minutes for each appointment. To prevent tooth sensitivity, a gel of low viscosity with potassium nitrate and 2% sodium fluoride (Desenbize KF 2%, FGM) was applied for 10 minutes immediately after the clinical session. There was a one-week break between sessions.

The patients were monitored so that no bleaching gel came in contact with the gingiva, and patients were questioned about any discomfort or sensitivity. The groups were evaluated based on the difference in color change before and after the bleaching session, then after seven days, two weeks, one month and six months from completion of the bleaching treatment.

At the clinical evaluations before, during and after bleaching treatment, the degree of shade changes, tooth sensitivity and gingival irritation was established for all patients. After seven days, upon completion of the bleaching treatment, patients received a questionnaire asking them to evaluate the bleaching treatment. Using the scale: none, slight, moderate or a lot, patients were asked how much they felt the procedure whitened their teeth. They were also asked if they would recommend the bleaching treatment to others, using the criteria: yes, maybe and no.

## RESULTS

### 1. Instrumental Evaluation—Spectrophotometer

The results of the instrumental method (spectrophotometer) that evaluated the variables (group and time) through the ANOVA tests in all groups (G1, G2, G3 and G4) matched the hypothesis of equality between the values of  $\Delta E$  for the group and time variables where  $p=0.999993$ . The averages of the results are shown in Figures 5 and 6.

### 2. Visual Evaluation—Color Scale

The results of the visual method (shade evaluation) that evaluated the variable (group and time) through the ANOVA tests in groups G1, G2, G3 and G4 matched

the hypothesis of equality between the values of ΔE for the group and time variables where  $p=1.00000$ .

### 3. Dental Sensitivity and Gingival Irritation

The clinical evaluation results are shown in Tables 4 and 5. Due to the low molecular weight of the peroxide and elevated usage, some patients presented with brief dental sensitivity (Table 4), but there was no significant difference between the groups. Sensitivity and gingival irritation were recorded as: none, slight, moderate or severe.

Sixty-seven percent of the patients recorded having side effects, of those, 63% recorded dental sensitivity and 4% gingival irritation. Of the 56% of patients who confirmed having tooth sensitivity, 92% recorded having slight and moderate sensitivity. Tooth sensitivity was recorded immediately following the initial bleaching application and was greater after the second appointment for all participating groups. No sensitivity was recorded 24 hours after treatment.

Gingival irritation was recorded on patients where the bleaching gel came in contact with the gingiva due to a gingival dam not being used.

### 4. Patients Satisfaction

Seven days after completion of the bleaching treatment, a questionnaire was given to all subjects, asking them to evaluate the treatment. Thirty-six of the 40 patients (92.5%) recorded that the treatment whitened their teeth “moderately” and “a lot,” and just three patients (7.5%) who belonged to groups G3 and G4 recorded “a slight” difference (Table 6).

The patients were asked if they would recommend this treatment to others. Thirty-seven patients (94%) answered “yes” and three patients (6%) responded “maybe” (Table 7).

Their major concerns during treatment were its duration, which was approximately one hour per appointment, the labial retractor and tooth sensitivity after the bleaching sessions.

## DISCUSSION

In this clinical study, the in-office treatment with 35% hydrogen peroxide was used. These bleaching agents were used despite some *in vitro* and *in situ* studies that demonstrated alterations in the dental structure.<sup>10-12</sup>

Table 4: Dental Sensitivity During Bleaching Treatment

Group	Patients	None	Slight	Moderate	Severe
G1	10	4	2	4	0
G2	10	5	3	1	1
G3	10	2	3	4	1
G4	10	4	3	2	1

Table 5: Gingival Irritation During Bleaching Treatment

Group	Aux Sources	None	Slight	Moderate	Severe
G1	–	9	1	0	0
G2	Halogen	9	1	0	0
G3	LED	8	1	1	0
G4	LED + Laser	8	1	1	0

Table 6: Patient Evaluation After Treatment

Group	Patients	None	Slight	Moderate	A Lot
G1	10	0	0	3	7
G2	10	0	0	4	6
G3	10	0	2	2	6
G4	10	0	1	5	4

Table 7: Patients Answers in Regard to Recommending the Treatment to Others

Group	Active Source	Yes	Maybe	No
G1	–	10	0	0
G2	Halogen	9	1	0
G3	LED	9	1	0
G4	LED + Laser	9	1	0

Other authors provided evidence that these bleaching agents do not cause any type of alteration to the dental structure.<sup>13-18</sup> This divergence is justified by the different methods of study (time of evaluation, bleaching agents used, time of application, immersion of the specimens in artificial saliva between treatments, type of storage, bleaching agent pH, usage of fluoride, etc). When these studies are done under *in vivo* and *in situ* conditions, no alteration of the dental structure was recorded, as saliva prevents demineralization of bleached dental enamel.<sup>19</sup>

The various side effects verified in the *in vitro* studies were not recorded when these same studies were done under *in situ* conditions.<sup>20</sup> This study was performed *in vivo* for the purpose of testing the bleaching treatment in a clinical scenario.

This evaluation was done specifically on six maxillary anterior teeth (canine to canine). The duration of the applications during the bleaching treatment was standardized. The in-office treatment with 35% HP was used in two in-office sessions, with six applications of the bleaching gel (three applications at each appoint-

ment) conducted in all four groups. This standardized application technique simplified comparison of the results to other studies,<sup>17,21-23</sup> while it differed from other studies where the number of sessions and applications depended on patients' will and their consent.<sup>24-25</sup>

Tooth sensitivity and gingival irritation were measured and recorded using the following criteria: none, slight, moderate and severe, to simplify the evaluation. This differed from the study by Zekonis and others,<sup>26</sup> in which the evaluation was done in five categories: none, slight, moderate, considerable and severe.

The color scale was used for the visual evaluation. This method is the most common, as it is a quick, simple procedure and has been used successfully in many studies.<sup>19,24-25,27-30</sup> The shade selection process depends on numerous factors, such as source of light, tooth to be evaluated, evaluator experience and standardization and many other factors.<sup>31</sup> The current study was done in a single room with artificial lighting and two experienced, qualified evaluators, for the purpose of preventing any discrepancy in choosing the correct shade.

The instrumental evaluation has been preferred over the visual evaluation, because it makes the process more practical and statistically more reliable. The instrumental evaluation consisted of a spectrophotometer, colorimeter and image analysis techniques using software programs.<sup>18</sup>

The Easysshade spectrophotometer (Vita-Zahnfabrik, Germany) was used in the current study to compare and standardize shade evaluation. This method has become more popular in recent studies, because of its ease of use and it being lightweight, with precise measurement that allows analysis in small areas.<sup>29</sup>

A silicon guide was used, with openings in the middle third of each evaluated tooth, to standardize the shade measurement region by using the spectrophotometer before and after the bleaching treatment and to prevent light contamination during the evaluation, contrary to other studies that did not standardize the measurement region<sup>17,26</sup> or to conduct numerous measurements in various regions of the labial surface.<sup>30</sup> The non-standardization of the measurement region could interfere with the final results.

The auxiliary lights used in the in-office bleaching treatment were used to accelerate the action of the bleaching gel (35% HP) and are recommended by some manufacturers<sup>3,24,32</sup> for the in-office bleaching of vital teeth. Some manufacturers question whether the use of curing lights is necessary.<sup>4,5</sup> In the current study, no curing lights were used in group G1, only the bleaching gel with 35% HP was applied for posterior group comparisons (G2, G3 and G4).

Evaluating shade changes using the Easysshade spectrophotometer (Vita-Zahnfabrik, Germany) and the

Classical Vita Shade Guide (Vita-Zahnfabrik, Germany) over a six-month period revealed no significant difference between groups in which instrumental evaluation ( $p=0.281394$ ) and visual evaluation (color guide) ( $p>0.3895787$ ) was used. These results are similar to those by Ausschill and others<sup>24</sup> but differ from the clinical study of Zekonis and others,<sup>26</sup> in which the bleaching agent was used for a total of 60 minutes. In the current study, the bleaching agent was used for 90 minutes, which could be a contributing factor towards the superior results from this in-office bleaching treatment.

When comparing the two methods of shade evaluation (color guide and spectrophotometer), there were differences in the results, which correspond with other studies.<sup>2,17,30,33</sup> The authors of this study believe that similarities between the evaluating methods are the result of the spectrophotometer possessing the same measurement scale as the Vita Shade Guide and because both methods are standardized.<sup>34</sup>

There were no statistically significant differences observed with or without the use of curing light in relation to color change after the bleaching treatment. The use of activator sources (Halogen Light, LED and LED/Laser) for the purpose of accelerating the process of the bleaching gel and getting better results was not confirmed clinically.

Color stability was observed up to the sixth month after treatment. There was a slight color relapse after six months, but there were no statistically significant differences between the groups (Figures 5 and 6). However, a prolonged clinical study observed color descent to the original tooth shade.<sup>34</sup> Rosenstiel and others<sup>36</sup> monitored, *in vitro*, the color modification and its stability after one session of in-office bleaching with 35% HP activated with light for 30 minutes. That study observed a color relapse seven days after treatment, which differed from the current study. This discrepancy might be due to the lower number of bleaching sessions, the duration of the bleaching gel application, being an *in vitro* study and the introduction of new bleaching agents and techniques. The inclusion of light-cured gingival dams, chemical activators and the use of compounds that decrease tooth sensitivity have simplified treatment and demonstrated better results.<sup>23</sup>

To promote better color stability, the use of both in-office and at-home treatments has been recommended. This claim was not evaluated in the current study. With that method, the first bleaching session is done using 35% HP (in-office), followed by at-home bleaching.<sup>37</sup> This combination of bleaching treatments for vital teeth provides better results, because it reduces the length of treatment and lowers irritation of the gingival tissues and tooth sensitivity.<sup>23</sup> Another method for achieving better results is by using two application sessions (35%

HP) and three applications of the bleaching gel for each session, as was utilized in the current study.

The groups (G1, G2, G3, G4) were bleached in two clinical sessions, with a seven-day break between each session. Each session utilized a bleaching gel application lasting 45 minutes, totaling 90 minutes for the entire treatment to promote higher shade alteration and color stability.

The recorded tooth sensitivity was similar in both the number of patients and intensity. Sensitivity is strongly related to concentration, time and rate of usage of the bleaching gel.<sup>21,23,38</sup>

Tooth sensitivity probably occurred due to a high concentration of the bleaching gel and the length of application (35% HP, 45 minutes). Another factor that contributed to the increase in tooth sensitivity during the in-office bleaching treatment was the use of light and heat sources, which led to higher pulpal temperature.<sup>3</sup>

Tooth sensitivity occurred immediately following bleaching, but a higher degree of sensitivity was recorded after the second bleaching session, independent of the group evaluated. Tooth sensitivity that occurred immediately following bleaching was probably due to the high concentration of peroxide associated with a light source, increasing tooth temperature and the patient's sensitivity.<sup>33</sup>

A recent study observed that the bleaching treatment caused a therapeutic effect combined with an increase or decrease in oral bleeding and dental plaque and healthier gingival tissues, because certain hydrogen peroxide byproducts are antibacterial.<sup>39</sup> A low concentration of bleaching agent in contact with gingival tissues causes no noticeable clinical lesion. Local inflammation can occur in gingival tissues that are exposed to high concentrations of peroxide, but that inflammation is easily treated.<sup>39</sup>

In the current study, patients reported low gingival irritation probably because it was possible to safely control contact of the bleaching gel with the gingival margin by using light-cured gingival dams.

### CONCLUSIONS

1. The in-office bleaching agent used was effective for the whitening of vital teeth.
2. The in-office bleaching treatment of vital teeth with 35% hydrogen peroxide did not show improvement with the use of any auxiliary sources tested (halogen light, LED, LED/Laser).
3. There were no color stability differences up until the sixth month after the evaluation between the study groups.

(Received 24 March 2007)

### Acknowledgement

The authors thank Sara Behmanesh for revising this paper.

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# A Clinical Evaluation of Two In-office Bleaching Regimens With and Without Tray Bleaching

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## Clinical Relevance

In-office tooth bleaching, followed by at-home bleaching with trays, was shown to be more effective than in-office bleaching without at-home bleaching. Three 15-minute applications of an in-office bleaching agent were more effective than one 40-minute application.

## SUMMARY

**This study evaluated the degree of color change of teeth, the rebound effect and the sensitivities of teeth and gingiva associated with the use of an in-office bleaching agent followed by an at-**

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DOI: 10.2341/08-64

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**home bleaching agent to lighten stained teeth in an *in vivo* study. Thirty-seven subjects who met the Inclusion/Exclusion criteria were divided into two cells. Twenty-five subjects received three 15-minute in-office bleaching treatments in succession with 36% hydrogen peroxide (HP) on the maxillary anterior teeth, followed by at-home overnight bleaching with 15% carbamide peroxide (CP) for seven days on one side of the dental arch. Twelve other subjects received a 40-minute in-office bleaching treatment on their maxillary anterior teeth, followed by at-home overnight bleaching for seven days on one side of the dental arch with the same product. The cells of teeth on the other side of the dental arch received the same in-office treatment but were not bleached overnight for seven days.**

**Color was subjectively evaluated using the Vitapan Classical Shade Guide and was objectively evaluated using the Chroma Meter at the baseline appointment, immediately after in-office bleaching and at 4, 7 and 14 days and 3**

**months after the in-office treatment. For two weeks, the subjects completed sensitivity evaluations of gingival tissues and hard tooth tissues.**

**The cells that did not receive the at-home bleaching had significantly less color change than the cells that received at-home bleaching. The cell that was bleached for 40 minutes and received the at-home treatment had significantly less overall change ( $\Delta E$ ) at 14 days and 3 months than the cell that received three 15-minute treatments with the at-home treatment.**

**Throughout the study, the subjects in the three 15-minute treatment cells had less gingival and tooth sensitivity than the other cells.**

### INTRODUCTION

Cosmetic dentistry has become a very important part of the restorative dental practice. Patients have rated teeth as the most important feature of an attractive face.<sup>1</sup> Cosmetic procedures have become increasingly more desirable and, with improvements in the standard of living, patients are asking dentists about tooth whitening. Whiter teeth are perceived as being associated with health and beauty. It is the responsibility of dentists to offer techniques and expertise that can help patients achieve their goals safely. Vital tooth bleaching is a more conservative treatment for discolored teeth compared with restorative treatments, such as porcelain veneers, crowns or composite bonding.<sup>2</sup>

Hydrogen peroxide's ability to lighten tooth color is not fully understood, although it is known to diffuse through enamel and dentin relatively easily, because of its molecular weight.<sup>3</sup> There is a chemical theory that explains hydrogen peroxide's bleaching action. Active hydrogen peroxide breaks down into  $H_2O + O_2$  and forms a perhydroxyl-free radical ( $HO_2$ ) for a short period of time. The great oxidative power of the free radical may break-up the large macromolecular stain into smaller stain molecules.<sup>4</sup> The simpler molecules formed by the bleaching process reflect more light, changing the tooth's appearance to a lighter shade.<sup>5</sup>

Another theory for the mechanism of action of a peroxide is that it opens the carbon-ring of pigment molecules, converting them to chains that are lighter in color. Yellow double-bond carbon compounds are converted into almost colorless hydroxyl compounds.<sup>6</sup>

Bleaching with carbamide peroxide differs from hydrogen peroxide. First, carbamide peroxide breaks down into urea and hydrogen peroxide. Ten percent carbamide peroxide breaks down into two products: 6.6% urea + 3.4% hydrogen peroxide. The urea further breaks down into carbon dioxide and ammonia.<sup>8</sup> The hydrogen peroxide breaks down into  $H_2O + O_2$  through an intermediary perhydroxyl free radical,  $HO_2$ .

Throughout the past decade, tooth bleaching has undergone significant changes. Currently, patients have the choice of undergoing vital tooth bleaching procedures in the dental office or at home. About 10 years ago, a study was reported<sup>7</sup> where in-office and at-home bleaching treatments were used consecutively.

In-office bleaching uses 15-38% hydrogen peroxide gel or liquid.<sup>8</sup> Because of the high concentration of the agents used, oral soft tissues must be protected during the procedure. Protecting the soft tissues and isolating the teeth can be accomplished with a rubber dam,<sup>9-10</sup> light polymerized resins<sup>6</sup> or other materials. Following placement of a tissue protectant, hydrogen peroxide gel or liquid is applied to the discolored teeth.

Carbamide peroxide and/or hydrogen peroxide is used for at-home bleaching treatments. There are many different concentrations of carbamide and hydrogen peroxide offered by manufacturers. They range from 10% to more than 45% for carbamide peroxide and from 3% to 14% for hydrogen peroxide. Ten percent carbamide peroxide is equivalent to approximately a 3.4% solution of hydrogen peroxide.<sup>6</sup>

Today, many of the manufacturers recommend at-home bleaching after the initial in-office procedure. When bleaching with carbamide peroxide, the manufacturers recommend patients use custom-fitted trays overnight or for a minimum of two hours a day. When bleaching with hydrogen peroxide, the manufacturers recommend 30 minutes to one hour a day.

The current study: 1) evaluated the effectiveness of a 36% hydrogen peroxide in-office system used once for 40 minutes or 3 times for 15 minutes each, 2) evaluated the effectiveness of use and non-use of a 15% carbamide peroxide agent in a tray for seven nights on one-half of the maxillary arch of teeth whitened in the dental office 3) and, in the above cases, documented reversal in tooth whitening for three months. The results of the current study will help clinicians choose the best methods and times for tooth whitening.

### METHODS AND MATERIALS

Prior to participating in this bleaching study, patients signed a consent form. The form and research protocol were reviewed and approved by the Institutional Review Board at Indiana University-Purdue University, Indianapolis (IUPUI), Indianapolis, IN, USA. The inclusion and exclusion criteria used in the study are listed in Table 1.

All subjects received a complete oral prophylaxis by a licensed hygienist or dentist at least one week, but not more than two months prior to starting the bleaching process. Extrinsic stains were removed with a fluoride dental prophylaxis paste (NUPRO Paste, Dentsply Professional Division, York, PA, USA).

The subjects were informed that this study required in-office bleaching followed by at-home bleaching. The four study groups (Table 2) were defined using a 2 x 2 factorial design with three 15-minute applications or a single 40-minute application of NUPRO White Gold in-office tooth whitener (NGWIO) (Dentsply Professional Division) containing 36% HP with and without the use of NUPRO White Gold at-home gel (NWGAH) (Dentsply Professional Division) containing 15% CP in a tray for seven days. The tooth whitening process was performed on the subjects' maxillary anterior teeth. Because of the split-mouth design, both sides of the subjects' mouths received the same number of in-office applications, with only one side of the maxillary anterior dental arch receiving the at-home gel application. Twenty-five subjects received three 15-minute applications NGWIO (D3) and 12 subjects were given one 40-minute application of the same whitening gel (D1).

At the beginning of the baseline appointment, a color evaluation was performed using two methods: 1) subjective shade guide matching of the middle-third of the maxillary anterior teeth with the Vitapan Classical Shade Guide (Vita Zahnfabrik, Bad Sackingen, Germany) arranged by value order (lightest to darkest) (Table 3) and 2) use of a color measuring device to determine the color of the middle-third of the teeth (Chroma

Meter, Model CR-321, Minolta, Ramsey, NJ, USA). Three independent readings were taken and the mean of their value was plotted. All the evaluations were conducted in the same geographic location with color-corrected overhead lighting, with the same examiner performing all of the evaluations.

The colorimeter was used to measure the color of teeth based on the CIE L\*a\*b\* color space system. This system was defined by the International Commission on Illumination in 1967 and is referred to as CIELAB.<sup>11</sup> L\* represents the value (lightness or darkness), a\* is the measurement along the red-green axis and b\* is the measurement along the yellow-blue axis. A positive a\* value indicates the depth of red, while a negative a\* value indicates green. Alternatively, a positive b\* value indicates the depth of yellow and a negative b\* value indicates blue. The total color difference or distance between two colors ( $\Delta E$ ) was calculated using the formula:  $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ .<sup>11</sup>

The soft tissues were evaluated on all maxillary and mandibular teeth using a Loe-Silness Gingival Index.<sup>12</sup> The Loe-Silness Gingival Index criteria are: 0=no inflammation; 1=slight inflammation (no bleeding); 2=moderate inflammation (delayed bleeding); 3=severe inflammation (spontaneous bleeding). At the same

appointment, all subjects had one alginate maxillary arch impression taken with Jeltrate PLUS (Dentsply LD Caulk Division, Milford DE, USA), from which a study model was made from Silky-Rock stone (Whip Mix Corp, Louisville, KY, USA). A custom tray was fabricated with reservoirs for the maxillary arch. The tray was trimmed on the labial and lingual surfaces so that it was slightly shy of the gingival soft tissue margin.

The subjects and all personnel involved with the treatment wore protective eyewear during the in-office whitening procedures. Isolation of the gingival tissue from the bleaching agent was accomplished using a light-cured resin dam (NUPRO White Gold Gingival Dam, Dentsply Professional Division).

Table 1: Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
<ul style="list-style-type: none"> <li>Have all six maxillary anterior teeth.</li> <li>Have no maxillary anterior teeth with more than 1/6 of their labial surface covered with a restoration.</li> <li>Be willing to sign a consent form.</li> <li>Be at least 18 years of age.</li> <li>Be able to return for periodic examinations.</li> <li>Be willing to refrain from the use of tobacco products during the study period.</li> <li>Have maxillary anterior teeth that are between A-3 and C-4 shades on the Vita Classic Shade Guide.</li> </ul>	<ul style="list-style-type: none"> <li>Have a history of any medical disease that may interfere with the study or require special considerations.</li> <li>Use tobacco products during past 30 days.</li> <li>Have current or previous use of professionally applied or prescribed "in-office" or "at-home" bleaching agents.</li> <li>Have a gross pathology in the oral cavity (excluding caries).</li> <li>Have a gingival index score greater than 1.0.</li> <li>Pregnant or lactating women.</li> <li>Tetracycline-stained teeth.</li> </ul>

Table 2: Study Groups

	Three 15-minute In-office Applications (36% HP)	One 40-minute In-office Application (36% HP)
7 day at-home gel (15% CP)	D3+	D1+
No at-home gel	D3-	D1-

Table 3: Vitapan Classical Shade Guide Tabs From Lightest to Darkest in Numeric Order

Lightest		→	→	→	→	→	→	→	→	→	→	→	→	Darkest	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
B1	A1	B2	D2	A2	C1	C2	D4	A3	D3	B3	A3.5	B4	C3	A4	C4

NWGIO was applied to the facial surfaces of the teeth and allowed to remain during treatment. The teeth were then rinsed and dried, but not desiccated. After drying, the resin dam was removed. Shade tab matching, photographs and colorimeter readings were accomplished immediately after the in-office bleaching process.

The subjects were asked to flip a coin to randomly select on which side, right or left, they would wear the at-home bleaching tray. The tray was cut, and the subjects were shown how to load it with gel, place it on the teeth and remove the gel from the tray after using it overnight. The subjects were given the half-mouth-bleaching tray to wear overnight on one-half of their maxillary arch for seven days. The patients placed NWGAH in the tray and used it overnight, starting with the day of the in-office bleaching. The subjects returned at 4, 7, 14 and 84 days after the in-office procedure for the same color evaluations and photos that were obtained during the baseline evaluation.

Throughout the 84 days of the study, the subjects were asked to brush their teeth with a non-whitening dentifrice (Crest Cavity Protection, Procter & Gamble, Cincinnati, OH, USA) at least twice a day to standardize their oral hygiene. All subjects were given a sensitivity sheet on which to record daily the maximum level of tooth and gingival sensitivity on the bleached side of their maxillary arch during the bleaching treatment and for the seven days after completing the at-home treatment. The subjects used a VAS (Visual Analog Scale) scale to record their daily tooth and/or gingival sensitivity. VAS is an instrument that measures a characteristic or attitude that is believed to span a continuum of values and cannot be objectively measured.<sup>13</sup> Subjects who had more than a moderate degree of sensitivity on either side of their maxillary arch were asked to return to the dental school to receive a potassium nitrate desensitizing gel.

Analyses of the whitening effect were performed separately for the D1 and D3 subgroups. The treatments were compared for differences in sensitivity, baseline color and color change using repeated measures analysis of variance (ANOVA). The ANOVAs for gingival and tooth sensitivity included terms for treatment, day and treatment-by-day interaction. The ANOVAs allowed for a correlation between the two treatments within a subject, different variances for each day and different correlations between days within a treatment. The analyses for sensitivity were performed using the ranks of scores that satisfy the ANOVA assumptions. The ANOVAs for baseline color included terms for

tooth type, treatment and type-by-treatment interaction, as well as correlating the teeth within a subject. The ANOVAs for color change included terms for baseline color, tooth type, treatment, exam and interactions between the tooth type, treatment and exam. The ANOVAs allowed for a correlation between the two treatments within a subject, different variances for each exam and different correlations between exams within a treatment. The analyses for gingival and tooth sensitivity were similar; *p*-values were not adjusted for multiple comparisons.

Additional analyses were performed to compare the D1 and D3 studies. The analyses were similar to those described above, with additional terms to match the number of in-office applications and interactions with the number of applications

**RESULTS**

There were 34 subjects who attended all of the evaluations; two subjects did not attend the three-month examination but were still included in the analyses; one other subject dropped out of the study due to a family emergency and was not included in the analyses. In the D1 group, the mean age was 50.8 years and included six (50%) females and six (50%) males. The D3 group mean age was 56.6 years and had 16 (67%) females and 8 (33%) males. The youngest subject was 35 years in both the D1 and D3 group, while the oldest was age 70 in the D1 group and age 78 in the D3 group.

At the baseline measurements, there were no color differences between D1 + and D1 - (*p*=0.56 for L\*, *p*=0.26 for a\*, *p*=0.78 for b\* and *p*=1.00 for shade guide). And, there were no baseline color differences between D3 + or D3 - (*p*=0.78 for L\*, *p*=0.72 for a\*, *p*=0.31 for b\* and *p*=1.00 for shades guide) (Table 4). However, the D3 subjects had a significantly higher baseline b\* (*p*=0.0081) than the D1 subjects. There were no other baseline color differences between D1 and D3 (*p*=0.88 for L\*, *p*=0.97 for a\*, *p*=0.72 for shade guide). The color changes in E and the shade guide are illustrated graphically in Figures 1 and 2. The data for those graphs are also documented (Table 5).

The D1- and D1+ treatments were not significantly different immediately after in-office bleaching (*p*>0.22). However, all of the other follow-up examinations after in-office bleaching in the D1- group had significantly less color change ( $\Delta L^*$ ,  $\Delta a^*$ ,  $\Delta b^*$ ,  $\Delta E$ ,  $\Delta$ shade guide) than D1+ (*p*<0.04). The color change did not sta-

Table 4: Mean Baseline Color (SD)

Group	N	L*	a*	b*	Vita Shade
D3+	24	47.39 (2.61)	-0.46 (0.57)	3.59 (1.92)	13.19 (1.66)
D3-	24	47.48 (2.53)	-0.48 (0.54)	3.93 (2.19)	13.19 (1.66)
D1+	12	48.01 (2.07)	-0.42 (0.32)	1.88 (2.10)	12.97 (1.94)
D1-	12	48.26 (1.92)	-0.53 (0.26)	1.98 (2.02)	12.97 (1.94)

Table 5: Mean Color Change (SD)

Group	Day	N	$\Delta L^*$	$\Delta a^*$	$\Delta b^*$	$\Delta E$	$\Delta Vita$ Shade
D3+	Post	24	4.08 (0.31)	-0.42 (0.06)	-2.69 (0.17)	5.05 (0.32)	-6.40 (0.52)
	4	24	6.84 (0.48)	-1.03 (0.09)	-4.25 (0.24)	8.26 (0.48)	-8.44 (0.53)
	7	24	7.72 (0.51)	-1.28 (0.09)	-4.65 (0.25)	9.23 (0.52)	-9.04 (0.56)
	14	24	4.62 (0.50)	-0.95 (0.09)	-3.59 (0.31)	6.13 (0.54)	-8.26 (0.65)
	84	23	2.58 (0.21)	-0.79 (0.08)	-2.58 (0.19)	3.92 (0.22)	-7.45 (0.51)
D3-	Post	24	3.86 (0.35)	-0.40 (0.06)	-3.03 (0.31)	5.10 (0.44)	-6.38 (0.53)
	4	24	2.54 (0.27)	-0.47 (0.05)	-2.02 (0.32)	3.59 (0.35)	-5.82 (0.47)
	7	24	1.29 (0.18)	-0.41 (0.05)	-1.18 (0.27)	2.29 (0.26)	-5.68 (0.46)
	14	24	1.17 (0.18)	-0.35 (0.05)	-1.36 (0.27)	2.25 (0.27)	-5.33 (0.59)
	84	23	1.27 (0.22)	-0.34 (0.05)	-1.28 (0.22)	2.26 (0.23)	-4.87 (0.52)
D1+	Post	12	5.22 (0.48)	-0.36 (0.09)	-2.97 (0.32)	6.10 (0.54)	-6.25 (0.86)
	4	12	6.56 (0.50)	-1.21 (0.09)	-4.12 (0.27)	7.92 (0.50)	-8.58 (0.71)
	7	12	7.12 (0.54)	-1.46 (0.10)	-4.28 (0.35)	8.53 (0.56)	-9.28 (0.57)
	14	12	3.07 (0.57)	-1.09 (0.12)	-2.38 (0.43)	4.49 (0.60)	-8.69 (0.46)
	84	11	1.03 (0.32)	-0.64 (0.06)	-1.34 (0.28)	2.26 (0.31)	-7.27 (0.92)
D1-	Post	12	5.24 (0.48)	-0.40 (0.06)	-3.21 (0.32)	6.26 (0.54)	-6.25 (0.86)
	4	12	2.25 (0.44)	-0.73 (0.07)	-1.95 (0.41)	3.40 (0.51)	-5.61 (0.85)
	7	12	0.62 (0.48)	-0.65 (0.07)	-0.93 (0.39)	2.41 (0.37)	-4.39 (0.66)
	14	12	0.00 (0.43)	-0.47 (0.06)	-0.37 (0.35)	1.77 (0.33)	-4.36 (0.70)
	84	11	-0.08 (0.32)	-0.28 (0.06)	-0.27 (0.46)	1.73 (0.39)	-4.24 (0.75)

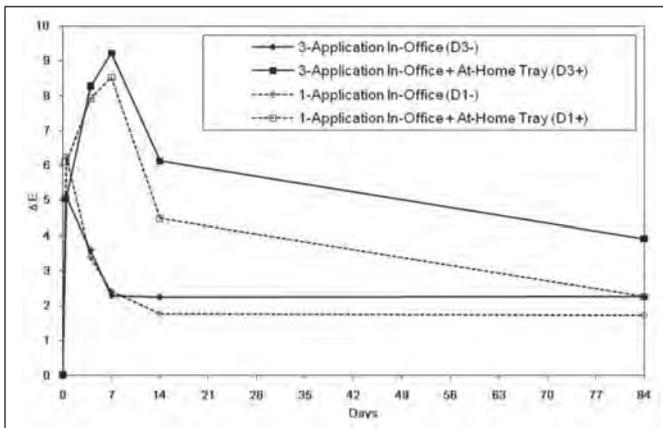


Figure 1: Mean change in E for in-office and in-office + at-home tray.

bilize for either product upon completion of the current study.

The D3- and D3+ treatments were not significantly different immediately after in-office bleaching ( $p>0.37$ ). However, all of the other follow-up examinations after in-office bleaching in the D3- group had significantly less color change ( $\Delta L^*$ ,  $\Delta a^*$ ,  $\Delta b^*$ ,  $\Delta E$ ,  $\Delta$ shade guide) than D3+ ( $p<0.0001$ ). Color change did not stabilize for either D3- or D3+ upon completion of the study, which was an unexpected result. The D1+ group had significantly less overall color change ( $\Delta E$ ) at 2 weeks ( $p=0.0417$ ) and 12 weeks ( $p=0.0155$ ) compared with the D3+ group after at-home bleaching.

There were indications of a treatment-by-day interaction for sensitivity ( $p=0.02$  for tooth sensitivity of D1 and  $p=0.07$  for D3,  $p=0.001$  for gingival sensitivity of D1 and  $p=0.06$  for D3), indicating that the treatment comparisons need to be evaluated separately for each day. The D1- group had significantly lower tooth sensitivity (Figure 3) than D1+ for day 5 ( $p=0.0471$ ), and D3- had significantly lower sensitivity than D3+ for days 4, 5 and 6 ( $p<0.04$ ). The D1- group had significantly lower gingival sensitivity (Figure 4) than D1+ for day 1 ( $p=0.0116$ ) and D3- had significantly lower sensitivity than D3+ for days 5 and 6 ( $p<0.02$ ). D1 had significantly higher tooth sensitivity ( $p=0.0478$ ) and gingival sensitivity ( $p=0.0029$ ) than D3.

### DISCUSSION

In-office bleaching has been shown to lighten teeth rapidly; however, there is often a considerable reversal of tooth whitening within two weeks of bleaching.<sup>14-16</sup> At-home mouthguard bleaching usually requires two-to-three weeks of treatment, but, generally, there is less of a reversal of tooth whitening than with in-office treatment. Combining both forms of treatment should shorten the bleaching time for clinicians and increase the “whitening” effect for patients. In the current study, a new in-office bleaching gel with a 36% hydrogen peroxide concentration was evaluated for one week in a single blind, split mouth design study with and without at-home bleaching using 15% carbamide peroxide in a tray with reservoirs. The current study evaluated the subjective and objective evaluation of tooth

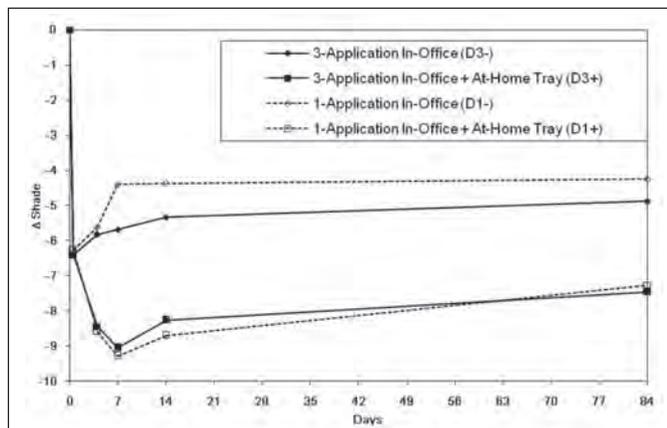


Figure 2: Mean change in Vita Shade for in-office and in-office + at-home tray.

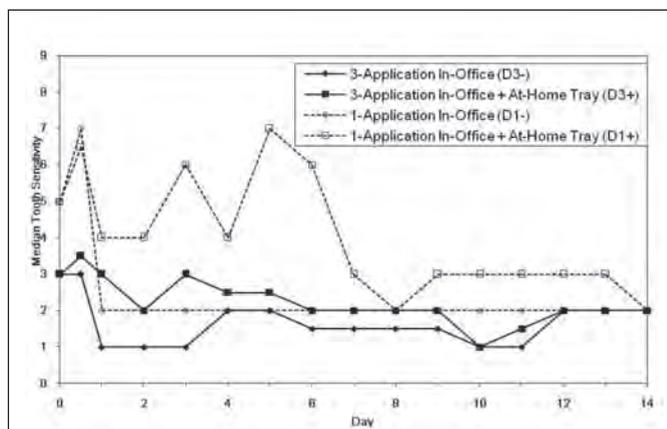


Figure 3: Tooth sensitivity for in-office and at-home tray.

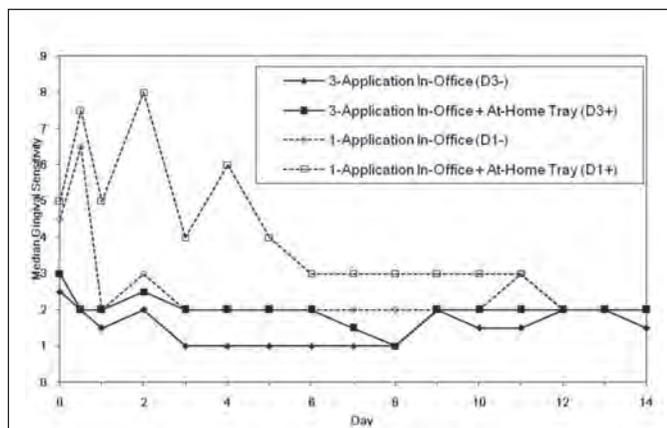


Figure 4: Gingival sensitivity for in-office and at-home tray.

color and reversal of color that occurs with one 40-minute gel application on 12 subjects or three 15-minute gel applications on 25 subjects.

The half-mouth design was used in five previous at-home or in-office studies.<sup>17-21</sup> Indications of crossover were evaluated between the two sides of the mouth by examining the means of the centrals and laterals, as well as the product comparison conclusions for the centrals and laterals. If crossover occurred, one would expect to see a mixing of the data results for the centrals when there were clear differences for the laterals. No consistent effects were observed throughout the five studies, indicating that there is no crossover effect with this study design.

The findings showed that both in-office bleaching treatments associated with at-home bleaching for seven days provided significant differences in L\*, a\*, b\*, E and shade guide change measurements when compared to the teeth without at-home bleaching treatment. These results show that the new product worked well and that at-home bleaching increased the whitening effect of in-office bleaching treatments.

Comparing the single 40-minute application and the three 15-minute application treatments, there was a significant difference in overall color change ( $\Delta E$ ) at two weeks ( $p=0.0417$ ) and 12 weeks ( $p=0.0155$ ). Delta E data indicates that D3+ was significantly lighter than D3- and D1- after three months.

Gingival and tooth sensitivity were less in the D3-cell during the entire study, compared with the other cells in the study. Three 15-minute gel applications increased the whitening effect and decreased gingival or tooth sensitivity.

Several studies compared different in-office tooth whitening application times and agents.<sup>7,22-23</sup> For five days, Kugel and others reported on using 35% HP with and without 15% CP in a tray twice a day for one hour.<sup>7</sup> They reported that, immediately after the tooth whitening regimens, the group receiving only the in-office treatment lightened 4.8 Vita shades, and the group receiving the in-office and at-home treatments lightened 7.1 shades. Deliperi and others compared using 35% HP (Group 1) and 38% HP (Group 2) three times in succession during the same appointment or using it for 30 minutes followed by 10% CP in custom-formed trays for 60 minutes on three successive days.<sup>22</sup> In Group 1, Deliperi and others reported a mean change of 8.9 Vita shades immediately after bleaching and a change of 7.2 shades seven days after bleaching. In Group 2, there was a mean change of 9.1 shades immediately after bleaching cessation and a 7.2 shade change one week after bleaching cessation. Papathanasiou and others had subjects bleach with a 15% in-office bleaching agent for 30, 45 and 60 minutes.<sup>23</sup> One day later, the subjects began using an at-home 10% CP agent in a custom-fitted tray for seven successive nights. Those results documented a 4.9 Vita shade change immediately after a 30-minute in-office

treatment, a 6.4 shade change after a 45-minute treatment and a 5.1 shade change after a 60-minute treatment. After seven days of 10% CP at-home usage, those subjects who had initially bleached for 30 minutes had a shade change of 7.2; those subjects bleaching for 45 minutes had an 8.9 shade change and those who bleached for 60 minutes had a 9.0 shade change. The current study reported a 6.25 to 6.40 Vitapan color shade guide tab change immediately after in-office bleaching and a 9.04 to 9.28 Vitapan color shade tab change after a combination of in-office and at-home bleaching for one week.

There are only two *in vivo* studies that determined the perceptibility of color using a colorimeter.<sup>24-25</sup> In one study,<sup>24</sup> it was determined that the mean color of 3.7 Delta E units, which existed between composite veneers and sound teeth, was rated as a perfect match in the oral environment. In the other *in vivo* study,<sup>25</sup> half of the observers perceived a color difference of 2.6 Delta E units with interchangeable right and left denture teeth in a denture base. The current study reported that there were differences of 3.9, 2.3, 2.3 and 1.7 Delta E units after three months in the D3+, D3-, D1+ and D1- groups, respectively.

### CONCLUSIONS

The use of three applications of NUPRO White Gold in-office whitening significantly lightened teeth in the L\*, a\*, b\*, E and Shade Guide parameters. The use of NUPRO White Gold at-home following the in-office procedure in both cells where it was used produced greater lightening in all the parameters that were measured, compared with either of the other two cells, where at-home bleaching was not used.

The subjects who received three 15-minute treatments had less gingival and tooth sensitivity than any of the other cells throughout the study.

### Acknowledgements

This study was supported by a grant from Dentsply Preventive Dentistry.

(Received 7 May 2008)

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## Literature Review

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# Review of the Effectiveness of Various Tooth Whitening Systems

BA Matis • MA Cochran • G Eckert

### Clinical Relevance

Tooth whitening is observable with all methods of bleaching. Dentist-prescribed overnight bleaching was shown to be the most effective method of bleaching.

### SUMMARY

**This review compares nine published studies conducted at the Indiana University School of Dentistry. Twenty-five products in four different systems were evaluated using the Trubyte Bioform Color Ordered Shade Guide and a Chroma Meter. The dentist-prescribed overnight bleaching delta mean shade guide value (DSGV) 10 weeks post-bleaching was 13.2 and delta E value (DEV) 4.7; dentist-prescribed daytime bleaching DSGV 10 weeks post-bleaching was**

**10.5 and DEV 3.4; in-office bleaching DSGV 10 weeks post-bleaching was 6.7 and DEV was 2.1; over-the-counter bleaching DSGV two weeks post-bleaching was 7.2 and DEV was 4.1. A color difference of Delta E 2.6 is perceivable. Tooth whitening is observable with all methods of bleaching. Dentist-prescribed overnight bleaching was shown to be the most effective method of bleaching.**

### INTRODUCTION

“Doctor, I want a whiter, brighter smile. What kind of bleaching works best?” Today’s dentist is acutely aware of the value of tooth bleaching to his or her practice and patients, but they want to provide treatment based on reliable evidence. The challenge for dentists is to determine the effectiveness of various tooth-whitening systems, while keeping patients’ safety paramount. This has become more and more difficult, as manufacturers continue to provide new products that purport to be superior to others currently on the market. Numerous claims are made based on higher concentrations of an active agent, the addition of desensitizing agents, better

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DOI: 10.2341/08-74

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formulations or the use of lights or other innovations, although it is a well known fact that dental bleaching is primarily time- and concentration-dependent.<sup>1</sup>

While many studies have been published detailing the effectiveness of various bleaching agents, there are only a few that have looked at both in-office and at-home systems.<sup>2,3</sup> It is also very difficult to make valid comparisons between research accomplished at different sites using diverse instruments and techniques. Most published studies use the Vitapan classical Shade Guide (Vita Zahnfabrik, Bad Sackingen, Germany) for subjective evaluation, but it has not been demonstrated that the shade tabs are actually linear in color measurement.<sup>4</sup> The Trubyte Bioform Color Ordered Shade Guide is grouped according to the Munsell Color Notation (each tab identified by hue, chroma and value) and has a wider spectrum of shades, but this shade guide still cannot be interpreted as absolute. A new shade guide has recently been introduced with more equal color spaces and an extended tooth-whitening range.<sup>5</sup> Several different color-measuring instruments are being used for objective evaluation, but their values cannot currently be compared. In addition, the skill of the evaluator and lighting variables are other factors that need to be addressed and are challenging to control.

The American Dental Association (ADA) has recently revised its criteria for the Seal of Acceptance program with dentist-prescribed at-home,<sup>6</sup> in-office<sup>7</sup> and over-the-counter<sup>8</sup> products, certifying the safety and efficacy of those products to a certain measurable standard. Only one dentist-prescribed at-home product has been awarded the ADA Seal of Acceptance at this time.<sup>9</sup> Even though the guidelines for ADA acceptance have recently been revised for the efficacy of products, the biological safety criteria have not been changed since they were established in 1994.<sup>10</sup>

In an attempt to provide an evidence-base for the dental practitioner, the purpose of this review article is to compare the effectiveness of various methods of tooth whitening by evaluating articles where most of the objective and all of the subjective evaluations were conducted using the same instruments. All study protocols were approved by the IUPUI Institutional Review Board, Indianapolis, IN, USA, and informed consent statements were signed by the subjects in the nine referenced studies.

### COMPARABLE STUDIES

All of the studies cited in this review of tooth whitening agents:

- used the Trubyte Bioform Color Ordered Shade guide (Style A, Dentsply/York Division, Dentsply International Inc, York, PA, USA) as the subjective color evaluation instrument.
- were evaluated by the same person (except for one<sup>11</sup>) who has lectured to dental students on color and shade evaluation for more than 25 years.
- used the Chroma Meter CR 321 (Minolta Corporation, Ramsey, NJ, USA)<sup>12</sup> with the exception of two; one used the Chroma Meter CR 121,<sup>11</sup> and the other used the ShadeEye (Shofu Inc, Kyoto, Japan).<sup>13</sup> Each subject was evaluated for color using the Chroma Meter and utilized a customized cone that was disinfected between uses, while those evaluated with ShadeEye had a disposable cone used for each evaluation.
- were carried out in an area that had color-corrected lighting and were not influenced by outside light.
- used subjects who were enrolled with the same Inclusion/Exclusion criteria (Table 1), except for the study using over-the-counter products.<sup>13</sup> Smoking was not an exclusion factor in that study.

The data used in this review represent values from the time dental bleaching was discontinued, as it would not be appropriate to begin when the studies were initiated. The in-office products would be two weeks ahead in the reversal of color when compared with those products that have one or two weeks of bleaching before reversal of color would begin.

Some of the reported studies were carried out for a much longer period than other studies. The data for this comparison were carried out to only 10 weeks for those studies that go longer, so that products could be compared.

Due to space limitations, only E and shade guide values are presented in this review; however, L\*, a\* and b\* values are available from the referenced articles. The ADA states in the guidelines for acceptance of tooth bleaching products that the E value specified must be due to higher L\* and lower b\* values.<sup>6-8</sup> E values are included in the current review, because they come closest to the ability of the human eye to perceive color.

Each study was accomplished for a specific research objective. Six studies in this meta analysis were split-mouth design studies, where different sides of the mouth used a different formula, different times or concentrations. This is the most effective way to conduct clinical research on products, because, if all teeth are vital, then the potential for whitening of the contralateral teeth will be similar. It has been reported that crossover has not influenced color changes,<sup>14</sup> if trays are made carefully and excess gel is not dispensed into the trays at the time of testing. One of the split mouth

Table 1: Products, concentration, subject number, bleaching, time of bleaching, post bleaching and length of studies.

Study #	Products	Concentration	N	Bleaching	Time of Bleach	Post-Bleaching	Length of Study
3	Opalescence	10% CP	20	2 Weeks	Overnight	10 Weeks	12 Weeks
	StarBrite	35% HP	20	2 Weeks	2-3 x 10 Minutes	10 Weeks	12 Weeks
11	Opalescence	10% CP	30	2 Weeks	Overnight	22 Weeks	24 Weeks
	Placebo	0% CP	30	2 Weeks	Overnight	22 Weeks	24 Weeks
13	Whitestrip Supreme	10% HP	25	1 Week	2 x 30 Minutes	2 Weeks	3 Weeks
	Ranir Wrap	8% HP	26	1 Week	2 x 30 Minutes	2 Weeks	3 Weeks
	Ranir Wrap	8% HP	25	1 Week	30 Minutes	2 Weeks	3 Weeks
14	Opalescence	10% CP	25	2 Weeks	Overnight	4 Weeks	6 Weeks
	Opalescence	15% CP	25	2 Weeks	Overnight	4 Weeks	6 Weeks
15	Opalescence	15% CP + PF	32	2 Weeks	Overnight	10 Weeks	12 Weeks
	Nite White	16% CP +ACP	32	2 Weeks	Overnight	10 Weeks	12 Weeks
16	Rembrandt Xtra	16% CP	27	2 Weeks	2 Hours	10 Weeks	12 Weeks
	Rembrandt Xtra	16% CP	27	2 Weeks	2 Hours	10 Weeks	12 Weeks
17	Opalescence	20% CP	24	2 Weeks	2 x 60 Minutes	10 Weeks	12 Weeks
	Day White	7.5% HP	24	2 Weeks	2 x 60 Minutes	10 Weeks	12 Weeks
18	StarBrite	35% HP	20	1 Hour	In chair	11 Weeks	11 Weeks
	Opalescence Xtra B	38% HP	20	1 Hour	In chair	11 Weeks	11 Weeks
19	Accelerated	40% HP	4	15 Minutes	In chair	6 Weeks	6 Weeks
	ArcBrite	30% HP	4	1 Hour	In chair	6 Weeks	6 Weeks
	BriteSmile	15% HP	4	1 Hour	In chair	6 Weeks	6 Weeks
	Illumine	15% HP	4	1 Hour	In chair	6 Weeks	6 Weeks
	Niveous	27% HP	4	45 Minutes	In chair	6 Weeks	6 Weeks
	One-Hour Smile	35% HP	4	45 Minutes	In chair	6 Weeks	6 Weeks
	PolaOffice	35% HP	4	36 Minutes	In chair	6 Weeks	6 Weeks
	Zoom!	25% HP	4	1 Hour	In chair	6 Weeks	6 Weeks

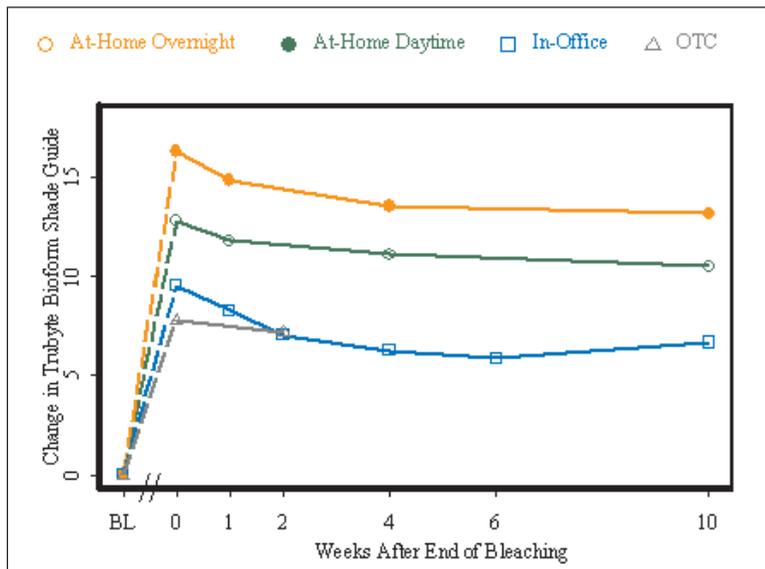


Figure 1. Mean delta shade of products evaluated at the Clinical Research Section of the Indiana University School of Dentistry. Baseline assessments were made two weeks before the end of bleaching for at-home night time and at-home daytime products one week before the end of bleaching for OTC products and approximately two hours before the end of bleaching for in-office products.

design studies compared the efficacy of a 10% CP vs a 15% CP.<sup>14</sup> Another study compared the sensitivity reduction that occurs using a 15% CP product containing potassium nitrate and fluoride (PF) compared with another 15% CP product containing amorphous calcium phosphate (ACP).<sup>15</sup> The objective of another study was to determine whether the use of reservoirs during daytime bleaching made a difference in the effectiveness of a product,<sup>16</sup> while another study tested the null hypothesis that there was no difference between using the same equivalent concentrations of HP in agents containing HP and CP<sup>17</sup> and the last split mouth study that compared the use of at-home vs in-office tooth-whitening agents.<sup>3</sup>

Three studies in this meta analysis were not accomplished as split-mouth design studies, but on different cells of subjects. Included are two studies where the authors tested the null hypothesis that there are no differences between the effectiveness of different in-office products.<sup>18-19</sup> The null hypothesis that there was no difference between the efficacy of using whitening strips compared with whitening

Table 2: Mean, 95% confidence interval for the mean, minimum, maximum and average percent loss of delta E and delta shade guide for each tooth whitening system.

Group		Weeks	Mean	95% CI	Min	Max	%Loss
<b>Delta E</b>	At-home Overnight	0	9.7	8.3 - 11.2	1.0	19.6	—
		1	6.7	5.2 - 8.2	1.4	18.6	31%
		4	4.9	3.5 - 6.4	0.4	15.9	49%
		10	4.7	3.0 - 6.5	1.6	13.4	51%
	At-home Daytime	0	6.6	4.6 - 8.5	1.7	15.6	—
		1	4.6	2.6 - 6.6	0.8	14.2	30%
		4	3.4	1.5 - 5.4	0.8	6.8	48%
		10	3.4	1.4 - 5.4	1.2	12.6	48%
	In-office	0	5.4	3.2 - 7.5	1.2	11.1	—
		1	3.0	0.4 - 5.5	0.9	9.8	45%
		2	2.3	0.0 - 5.2	1.0	7.1	57%
		4	2.0	0.0 - 4.1	0.7	6.1	63%
		6	1.9	0.0 - 4.7	0.8	4.4	65%
		10	2.1	0.0 - 4.3	1.2	6.3	60%
	OTC	0	4.6	1.8 - 7.3	0.8	7.3	—
		2	4.1	1.4 - 6.9	0.6	7.3	10%
<b>Delta Shade</b>	At-home Overnight	0	16.3	15.1 - 17.5	2.0	25.0	—
		1	14.8	13.6 - 16.1	1.0	25.0	9%
		4	13.6	12.3 - 14.8	0.0	22.0	17%
		10	13.2	11.8 - 14.6	1.0	23.0	19%
	At-home Daytime	0	12.8	11.1 - 14.5	5.3	20.0	—
		1	11.8	10.1 - 13.5	4.7	19.7	8%
		4	11.1	9.4 - 12.8	4.3	18.3	13%
		10	10.5	8.9 - 12.2	4.0	17.7	18%
	In-office	0	9.6	7.6 - 11.5	-1.3	19.2	—
		1	8.3	6.0 - 10.6	1.0	16.7	13%
		2	7.0	4.5 - 9.6	-1.3	14.0	26%
		4	6.3	4.3 - 8.2	-3.0	15.7	34%
		6	5.9	3.3 - 8.4	-3.0	14.8	39%
		10	6.7	4.8 - 8.5	-4.3	17.7	30%
	OTC	0	7.8	5.7 - 9.9	0.0	16.0	—
		2	7.2	5.2 - 9.3	0.0	16.0	7%

wraps was tested in one study.<sup>13</sup> The last of the nine studies was accomplished to determine the efficacy and clinical safety of 10% CP and was accomplished using a placebo vs 10% CP in separate subjects.<sup>11</sup>

All peer-reviewed published studies that were accomplished at the Clinical Research Section at the Indiana University School of Dentistry are included in this meta analysis. Table 1 identifies the studies, products used, concentrations, number of subjects, bleaching times and post-bleaching follow-up evaluations. These studies had examinations at slightly different follow-up times, so the data are summarized at the end of bleaching, then at approximately 1, 2, 4, 6 and 10 weeks after completion of the bleaching. Because all data from the individual studies was available, this meta analysis was performed using an ANOVA. The

ANOVA included terms for week, tooth type and product, as well as interactions among the three factors and baseline measurements as covariates. Random effects for study, subject, subject-by-week and subject-by-tooth type were also included. Products were grouped together to identify means, along with 95% confidence intervals for the means, ranges and average % loss from the end of bleaching (Table 2).

#### Dental Prescribed Overnight Bleaching

There are four studies in which a total of six products were used overnight.<sup>3,11,14-15</sup> Three of the studies used 10% CP,<sup>3,11,14</sup> and another study used 15% and 16% CP.<sup>15</sup>

The mean delta of the shade guide values of the six products was 16.3 immediately after bleaching and 13.2 ten weeks post-bleaching (Table 2, Figure 1). The

mean delta of the E value was 9.7 immediately after bleaching and 4.7 ten weeks post-bleaching (Table 2, Figure 2).

### Dental Prescribed Daytime Bleaching

There are two studies in which four products were used during the day.<sup>16-17</sup> One study used 16% CP, which was used for two hours once a day<sup>16</sup> either with or without reservoirs. The other study used products containing 20% CP and 7.5% HP. The products in that study were used twice a day for one hour.<sup>17</sup>

The mean delta of the shade guide values of the products was 12.8 immediately after bleaching and 10.5 ten weeks post bleaching (Table 2, Figure 1). The mean delta of the E value was 6.6 immediately after bleaching and 3.4 ten weeks post bleaching (Table 2, Figure 2).

### In-office Bleaching

There were three studies in which 11 in-office products were used.<sup>3,18-19</sup> One study used 35% HP, which was placed three times for 10 minutes at two different sittings.<sup>3</sup> The second study used 35% and 38% HP, which were placed three times for 20 minutes each at the same sitting.<sup>18</sup> The third study used eight products containing anywhere from 15%-40% HP.<sup>19</sup> The eight products were used for various periods of time (Table 1).

The mean delta of the shade guide values of the 11 products was 9.6 immediately after bleaching and 6.7 ten weeks post-bleaching (Table 2, Figure 1). The mean delta of the E value was 5.4 immediately after bleaching and 2.1 ten weeks post-bleaching (Table 2, Figure 2).

### Over-the-counter Bleaching

There is one study in which products were used three different ways.<sup>13</sup> One product contained 10% HP and was used for 30 minutes twice a day for one week. Both of the other agents contained 8% HP. One was used for 30 minutes once a day and the other for 30 minutes twice a day for one week.

The mean delta of the shade guide values of the three products was 7.8 immediately after bleaching and 7.2 two weeks post-bleaching (Table 2, Figure 1). The mean delta of the E value was 4.6 immediately after bleaching and 4.1 two weeks post-bleaching (Table 2, Figure 2).

## DISCUSSION

All groups in the study had at least 20 subjects, with the exception of one study, where eight products were evaluated using 32 subjects. This was considered a pilot study.<sup>19</sup> Six of the studies were half-mouth design studies.<sup>3,14-18</sup> This study design is the most valid study design for tooth-whitening research. Each tooth in the half-mouth responds to the agent that covers it. With well-

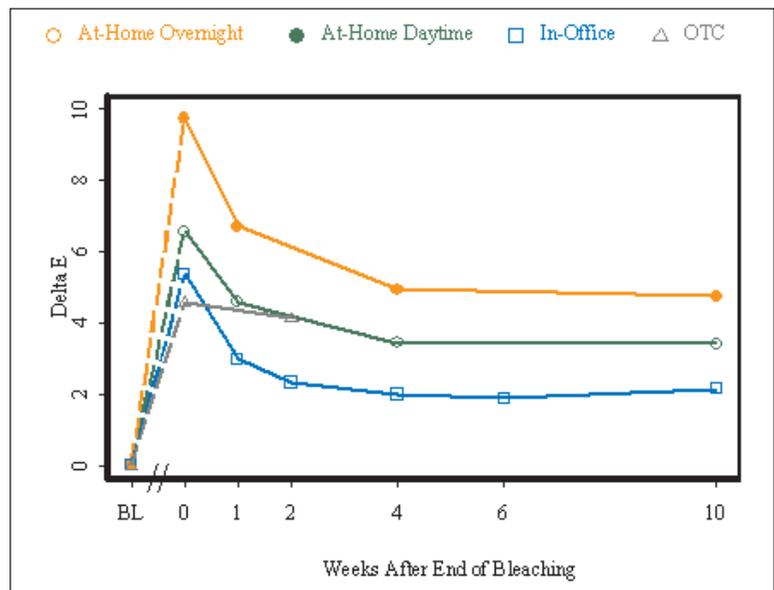


Figure 2. Mean delta E of products evaluated at the Clinical Research Section of the Indiana University School of Dentistry. Baseline assessments were made two weeks before the end of bleaching for at-home night time and at-home daytime products one week before the end of bleaching for OTC products and approximately two hours before the end of bleaching for in-office products.

made reservoirs, it has been determined that crossover effects, if there were any, are negligible.<sup>14</sup>

Manufacturer's recommendations were followed. Where reservoirs were recommended, they were placed. In the study of eight in-office products,<sup>19</sup> invitations to observe the procedures were extended to all of the manufacturers whose products were used in the study. Four of the eight manufacturers sent representatives to help ensure their products were used according to their instructions.

A study by Auschill and others evaluated the time it took for tooth whitening agents from different systems to reach six Vita shade guide tab changes.<sup>2</sup> These authors determined that it took 31.85 cycles of 30 minutes using an over-the-counter product, 7.15 cycles of using an at-home product overnight and 3.15 cycles of using an in-office product to reach the shade tab change desired.

The research center at Loma Linda University School of Dentistry, Loma Linda, CA, USA, routinely uses a colorimeter and Vitapan classical Shade Guide (Vita Zahnfabrik) to measure changes in color. In their study evaluating the effectiveness of three tooth-whitening systems, Li and others reported that the overnight system was the most effective of the three systems in a 21-day study.<sup>20</sup>

Neither of the studies that looked at three different systems carried out their evaluation periods past the endpoint of bleaching. It is important to look at color

reversal for at least four weeks after completion of the bleaching, so that the true endpoint can be identified, instead of a false endpoint that does not indicate what color patients can expect their teeth to remain for an extended period of time.

There are only two *in vivo* studies that have determined the perceptibility of color using a colorimeter.<sup>21-22</sup> In one study,<sup>21</sup> it was found that a mean color of 3.7 Delta E units between composite veneers and sound teeth was rated as a perfect match in the oral environment. In the other *in vivo* study,<sup>22</sup> it was found that 50% of the observers could perceive a color difference of 2.6 Delta E units with interchangeable right and left denture teeth in a denture base.

The current study compared products used for a certain time period. Bleaching is time- and concentration-dependent. The current study documents the relative lightening that has been shown to occur where research has been conducted with various systems according to manufacturers' recommendations.

### CONCLUSIONS

Tooth whitening is most effective when bleaching gel is placed in trays and the trays are used overnight. The second most effective system is placing the tooth whitening gel in a tray and using it during the daytime for shorter periods of time.

In-office tooth whitening systems cause the teeth to become light immediately after bleaching. However, two weeks after completing the bleaching treatment, over-the-counter tooth whitening was as effective as in-office tooth whitening. For this reason, most in-office systems recommend tray bleaching as a follow-up procedure to ensure long-term effectiveness.

(Received 29 May 2008)

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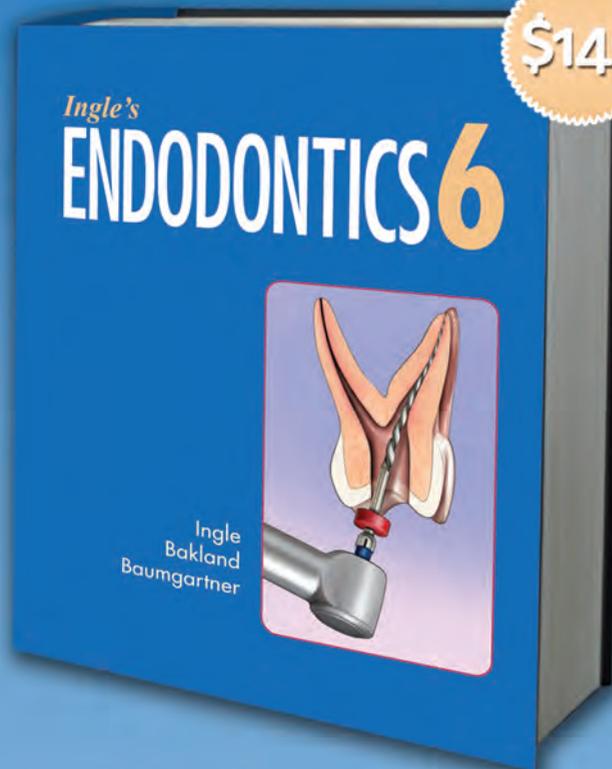
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# Continuing Dental Education Answer Sheet

Volume 16(4): Winter 2009

Deadline: March 15, 2010

Instructions:

1. Circle ONE letter for each question.
2. Return the completed answer sheet in the envelope provided.
3. Correct answers will be included with your next mailing. **Please keep a copy of this sheet.**

## Clinical Evaluation of In-office Dental Bleaching Treatments With and Without the Use of Light-activation Sources

- |    |   |    |   |    |   |     |   |     |   |    |   |
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## A Clinical Evaluation of Two In-office Bleaching Regimens With and Without Tray Bleaching

- |    |   |    |   |    |   |     |   |    |   |    |   |
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|    | c |    | c |    | c |     | c |    | c |    | c |
|    | d |    | d |    | d |     |   |    | d |    | d |
| 7. | a | 8. | a | 9. | a | 10. | a |    |   |    |   |
|    | b |    | b |    | b |     | b |    |   |    |   |
|    | c |    | c |    | c |     | c |    |   |    |   |
|    |   |    |   |    |   |     | d |    |   |    |   |

## Review of the Effectiveness of Various Tooth Whitening Systems

- |    |   |    |   |    |   |     |   |    |   |    |   |
|----|---|----|---|----|---|-----|---|----|---|----|---|
| 1. | a | 2. | a | 3. | a | 4.  | a | 5. | a | 6. | a |
|    | b |    | b |    | b |     | b |    | b |    | b |
|    | c |    | c |    | c |     | c |    | c |    | c |
|    | d |    | d |    | d |     | d |    |   |    |   |
| 7. | a | 8. | a | 9. | a | 10. | a |    |   |    |   |
|    | b |    | b |    | b |     | b |    |   |    |   |
|    | c |    | c |    | c |     |   |    |   |    |   |
|    | d |    | d |    |   |     |   |    |   |    |   |
|    |   |    | e |    |   |     |   |    |   |    |   |

Name: \_\_\_\_\_ Address: \_\_\_\_\_

