Comparison of Effectiveness of Two 10% Carbamide Peroxide Tooth-Bleaching Systems Using Spectrophotometric Measurements

SHIGEMI ISHIKAWA-NAGAI, DDS, MSD, PHD*
TAKAYUKI TERUI, DDS†
KANJI ISHIBASHI, DDS‡
HANS PETER WEBER, DMD§
MICHAEL FERGUSON, DDS‖

ABSTRACT

Purpose: The purpose of this study was to compare the color changes achieved with two commonly used bleaching systems on the basis of a spectrophotometric analysis.

Materials and Methods: Two commercially available 10% carbamide peroxide bleaching systems were used by a total of 48 individuals. Subjects who had intact natural maxillary anterior teeth void of any restorations or decay that had not been subjected to any prior bleaching were included. Opalescence 10% PF (Ultradent Products Inc., South Jordan, UT, USA) was used by 23 patients for 14 days, whereas Nite White Excel (Discus Dental, Culver City, CA, USA) was applied by 25 patients for the same duration. Tooth colors for the middle one-third region of maxillary central incisors and canines were measured with a spectrophotometer prior to bleaching and after 14 days of bleaching. Color difference ΔE and color coordinates L* (lightness), a* (redness), and b* (yellowness) of CIELAB color system (developed by the Commission Internationale de l'Eclairage) were calculated.

Results: Mean ΔE values for Opalescence ranged from 5.03 to 8.92 and from 5.84 to 9.61 for Nite White. The most significant factor of the color change was b* followed by L* and a*. L* values were higher after bleaching, whereas values for both a* and b* decreased. There were no significant differences between the two systems examined ($p < .05$).

CLINICAL SIGNIFICANCE

The two bleaching systems tested in this study produced a significant color change with ΔE values > 3.6, increasing L* values, and decreasing b* and a* values. There was no statistically significant difference in efficacy between the tested systems.

(*J Esthet Restor Dent* 16:368–376, 2004)

The use of peroxide for tooth bleaching has a history dating back more than a century.[1,2] In 1989 Haywood and Heymann introduced at-home bleaching using carbamide peroxide,[3] and over the years this has become a popular method for lightening teeth. In 1994 the Council on Scientific Affairs of

*Instructor, Department of Restorative Dentistry and Biomaterials Sciences, Harvard School of Dental Medicine, Boston, MA, USA
†Instructor, Department of Fixed Prosthodontics, Iwate Medical University, School of Dentistry, Iwate, Japan
‡Professor and chairman, Department of Fixed Prosthodontics, Iwate Medical University, School of Dentistry, Iwate, Japan
§Professor and chairman, Department of Restorative Dentistry and Biomaterials Sciences, Harvard School of Dental Medicine, Boston, MA, USA
‖Assistant professor, Department of Restorative Dentistry and Biomaterials Sciences, Harvard School of Dental Medicine, Boston, MA, USA

the American Dental Association (ADA) published guidelines for acceptance of home-use tooth-whitening agents.[4] During the past several decades, many studies on toxicologic evaluations of at-home tooth-bleaching agents, most of which contain 10% carbamide peroxide, have been published.[5] Research suggested that the cytotoxicity of bleaching agents with 10% carbamide peroxide appears to be lower or comparable to that of many other materials and agents commonly used in dentistry, such as composite resins, dentifrices, eugenol, and even mouthrinses. Furthermore, various clinical trials have demonstrated the clinical safety and efficacy of nightguard vital bleaching (NGVB).[6–9] Although there are many products for NGVB that employ 10% carbamide peroxide approved by the ADA, there are no objective comparisons of their efficacy.

The efficacy of bleaching has been examined using dental shade guides and gray scale.[10–13] However, perceptional evaluation of tooth shade using shade guides is not sufficiently precise and is highly subjective.[14–16] Most existing commercial shade guides do not represent the entire spectrum of tooth color,[17,18] and the lack of a standard color order may render this method of shade determination inconsistent. Also, this matching method depends on the operator's color perception, ambient light conditions, and the background against which the tooth is compared, all of which are subject to variance.

To analyze the efficacy of bleaching on tooth color changes, selection of a valid color-measuring instrument is pivotal. Many types of colorimeters and spectrophotometers have been used in dental research (such as those having d/0°, 0°/d, and 45°/0° geometry), and recently studies have even used digital cameras that cannot be precisely calibrated for color.[19,20] However, objects such as teeth and gingiva require the measurement of a small area and the need to overcome problems involving the effect of translucency. It is important to prevent light loss—a factor commonly referred to as "edge-loss error"—which can be caused by the walls of the aperture of the spectrophotometer or colorimeter. Edge-loss errors restrict the precise measurement of translucent specimens, especially L* (lightness), which will indicate lower-than-actual values.[21,22] To prevent edge-loss error, measuring geometry, either contact-type measurement or noncontact-type measurement, is significant. The ratio of illumination to detection area as a function of the energy of the illuminating light source is also essential to minimize edge-loss error. Based on previous research,[23,24] spectrophotometers that are not prone to edge-loss errors are gaining acceptance as important tools for dental applications. Furthermore, such spectrophotometers use multiple sensors to measure the spectral reflectance of an object at each wavelength or in each narrow wavelength range. Therefore, these spectrophotometers provide high accuracy and the ability to measure absolute colors.

The purpose of this study was to compare the color changes including quality and quantity achieved with two commonly used bleaching systems by using a spectrophotometer dedicated to dental usage that can measure tooth color without edge-loss error.

MATERIALS AND METHODS

Tooth Bleaching

Forty-eight subjects were included in this study (Table 1). Recruitment of subjects took place at the Iwate Medical University School of Dentistry in Japan and included males and females varying in age from 21 to 38 year (students, faculty, staff, and patients). There was no limitation for subject selection related to age, medication, or other

TABLE 1. STATISTICS OF SUBJECTS INCLUDED IN THIS STUDY.

	Gender		Age (yr)	
Bleaching System	Male	Female	21–29	30–38
Nite White	8	17	20	5
Opalescence	15	8	16	7

qualifiers, but subjects were required to be nonsmokers, have intact, natural maxillary anterior teeth void of any restorations or decay, and not have any prior bleaching experience. Furthermore, only subjects with original tooth color darker than A2 were included in this study. The study was approved by the Institutional Review Board of the Iwate Medical University. A written informed consent was obtained from each subject after a full explanation of the project.

Two 10% carbamide peroxide bleaching systems were used in a total of 48 patients. Subjects were randomly divided into two groups; 23 subjects were assigned to bleach with Opalescence 10% PF (Ultradent Products Inc., South Jordan, UT, USA) for 14 days, and 25 subjects were to bleach with Nite White Excel (Discus Dental, Culver City, CA, USA) for the same period. Impressions were made with alginate (Jeltrate, Dentsply Caulk, Milford, DE, USA), and study models were made with yellow stone (Dentstone Golden, Heraeus Kulzer, Hanau, Germany). For the group using Opalescence 10% PF, reservoirs were created by blocking out the labial aspects of all teeth from the incisal edge to approximately 0.5 mm coronal to the gingival margin using LC Block-Out Resin (Ultradent Products Inc.). The models for the Nite White Excel group were not blocked out, according to the manufacturer's guidelines. Custom bleaching trays were fabricated from 0.89 mm soft tray material (Soft-Tray, Ultradent Products Inc.) for the Opalescence system and from 0.4 mm soft tray for the Nite White system using vacuum forming techniques. The excess material was trimmed with a serrated trimming scissor on the labial and lingual surfaces, creating a scalloped margin pattern of the tray to protect the soft tissue, especially the interdental papillae. Trays were tried in the mouth, and adjustments were made as needed to optimize their fit. Subjects were instructed in the use of the bleaching gels and custom trays according to each manufacturer's guidelines. All subjects were asked to bleach for at least for 4 hours daily during the 14 days and were also asked to record the times when bleaching was started and finished on a provided daily log sheet.

Tooth Color Measurements and Evaluation of Tooth Sensitivity

Spectrophotometric measurements were made using a multispectral camera system (MSC-2000, Olympus Co, Tokyo, Japan) as shown in Figure 1. A 100 W halogen lamp (Olympus Co) was shone through filters to provide an approximately 25 W light source onto a 20.0 mm diameter illuminating area and a 15.0 mm diameter measuring area for a measuring time of 8 seconds. The spectrophotometer used 45°/0° geometry and was accurate to < 0.2 ΔE for repeated measurements. Prior to specimen color measurement, a calibration was performed with a standardized calibration tile (Ever-Colors, White, YONEDA Glass, Osaka, Japan). The probe was placed on the surface of the object, and the display confirmed the object and the area to be measured. The multispectral image data of the entire region were saved to a computer (PCV-R538DS, Sony, Tokyo, Japan) at once, and the area to be measured was selected on the display. Reflectance values ranged from 400 to 700 nm at 20 nm intervals.

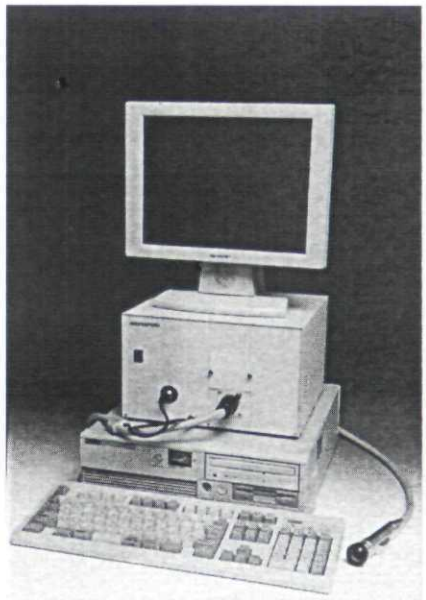

Figure 1. MSC-2000 spectrophotometer used in this study.

The tooth colors of the maxillary central incisors and canines were measured at their middle one-third region (3 mm height × 3 mm width) with a spectrophotometer prior to bleaching and after 14 days of bleaching. The measurement was performed three times for each

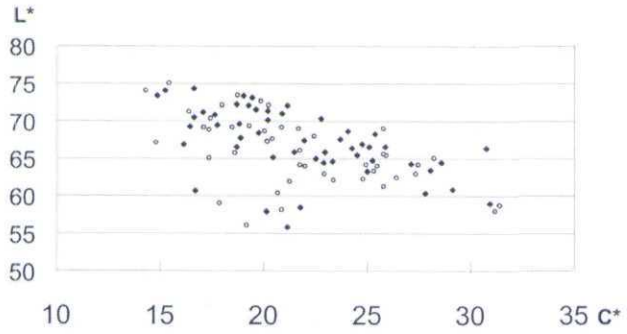

Figure 2. L versus C* color distribution map of the original tooth color prebleaching for two groups.*

tooth, and the average of these measurements was considered the measured data.

CIELAB color system is one of the uniform color spaces defined by CIE (the Commission Internationale de l'Eclairage) in 1976. It is presently one of the most popular color systems for measuring object color and is widely used in virtually all fields. CIELAB color coordinates L*, a* (redness), b* (yellowness), and C* ($[a^{*2} + b^{*2}]^{\frac{1}{2}}$) were provided from reflectance values taken from 400 nm to 700 nm in 20 nm intervals.

The prebleaching distribution of the original tooth color was examined to confirm that the two groups exhibited a similar color. The color changes between prebleaching and postbleaching were analyzed on a ΔL^*, Δa^*, and Δb^* distribution map, and the mean color difference ΔE ($[\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}]^{\frac{1}{2}}$) values for the two systems were compared using *t*-test. Subjects were also asked to record any tooth sensitivity on a daily log sheet using the following scores: 0 for no, 1 for slight, 2 for moderate, and 3 for severe sensitivity.

RESULTS

Baseline prebleaching color survey of the two groups indicated a very similar color distribution with the mean L* of 69.6 ± 3.1, a* of 3.2 ± 1.1, and b* of 19.1 ± 2.5 for Nite White and the mean L* of 69.4 ± 3.5, a* of 3.8 ± 1.7, and b* of 18.7 ± 2.4 for Opalescence (Figure 2). The statistical analysis (*t*-test) indicated no significant difference for L*, a*, and b* values between the two groups.

Color coordinates ΔL^*, Δa^*, and Δb^* for central incisors and canines were plotted for each bleaching system (Figures 3 and 4). The L* values for the central incisors increased for both systems, ranging from 0.2 to 9.8 in all but three subjects—one from the Nite White group and two from the

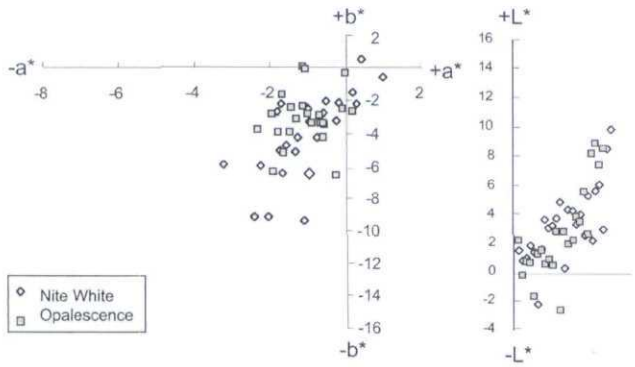

Figure 3. Comparison of color changes for two systems after bleaching of the central incisors.

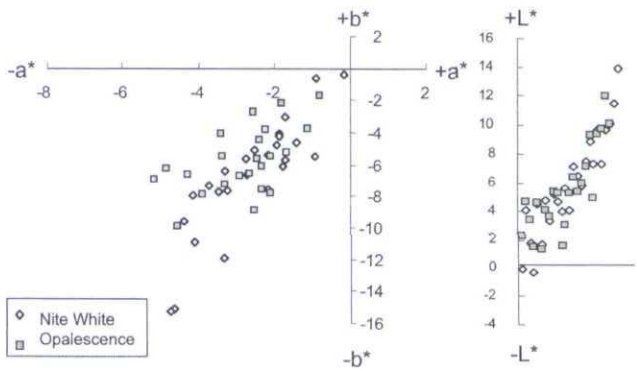

Figure 4. Comparison of color changes for two systems after bleaching of the canines.

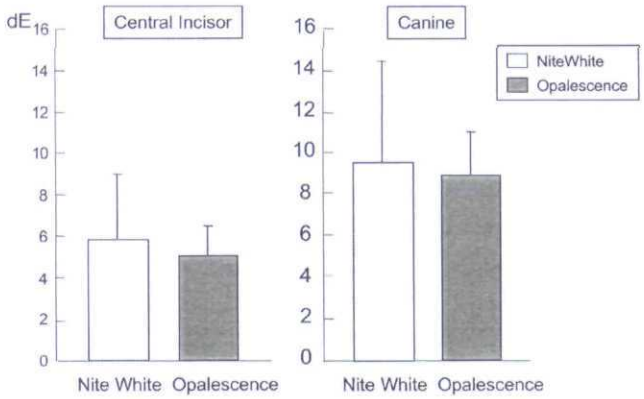

Figure 5. Mean color difference (ΔE[dE]) between pre- and postbleaching values.

Opalescence group—whose L* decreased. However, a* and b* for these three subjects also decreased, indicating a change toward lighter color. Although both a* and b* values decreased for these three subjects, the range of b* change was greater than that of a* change for both systems. The canines indicated greater positive changes of L*, a*, and b* than did the central incisors, and there was no subject whose a* and b* increased. Furthermore, the distribution of ΔL*, Δa*, and Δb* values for Nite White was wider than the distribution of values for Opalescence, as were values for canines compared with those of central incisors.

The mean ΔE values of Nite White and Opalescence for central incisors were 5.84 ± 3.05 and 5.03 ± 2.39, respectively. For the canines, the mean ΔE values were 9.61 ± 4.79 for Nite White and 8.92 ± 2.97 for Opalescence. Both systems led to distinguishable tooth color changes with ΔE value changes > 3.6, which is consistent with a clinically noticeable color difference. Although the mean ΔE values obtained with Nite White were greater than mean ΔE values for Opalescence for both central incisors and canines, the difference was not statistically significant (Figure 5). Mean ΔL*, Δa*, and Δb* values of the central incisor were 3.31 ± 2.58, −1.06 ± 0.97, and −4.10 ± 2.6 for Nite White, and 2.66 ± 3.16, −1.03 ± 0.66, and −3.09 ± 1.67 for Opalescence, respectively. The observed differences between the two systems were not statistically significant (Figure 6). Mean ΔL*, Δa*, and Δb* values for canines were 5.93 ± 3.5, −2.63 ± 1.23, and −6.78 ± 3.66 with Nite White, and 5.45 ± 2.97, −2.82 ± 1.12, and −5.80 ± 2.1 with Opalescence. These differences were not statistically significant (Figure 7).

The mean sensitivity score was 0.59 ± 0.64 for Nite White and 0.75 ± 0.58 for Opalescence. This difference is statistically insignificant. The mean frequency of sensitivity for 14 days was

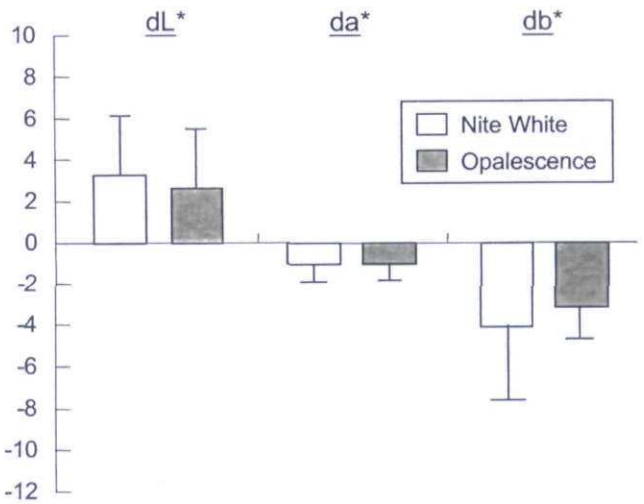

Figure 6. Mean ΔL (dL*), Δa* (da*), and Δb* (db*) values for the central incisors.*

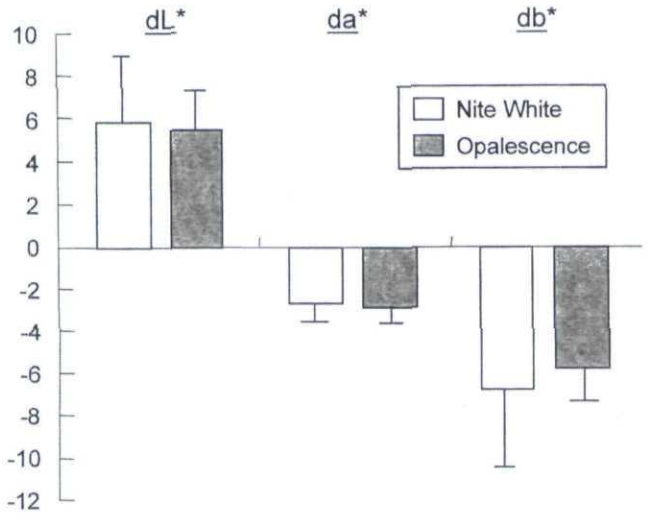

Figure 7. Mean ΔL (dL*), Δa* (da*), and Δb* (db*) values for the canines.*

39.88% for Nite White and 41.37% for Opalescence.

DISCUSSION

Carbamide peroxide is an oral antiseptic that has been used for many years in wound healing. A 10% carbamide peroxide solution contains approximately 3% hydrogen peroxide and 7% urea, and these materials are commonly found in the body and readily disposed of safely. Although vital bleaching with hydrogen peroxide has been an accepted procedure since the 1930s,[25] the first report regarding tooth bleaching using the NGVB technique was published only in 1989.[3] The guidelines of the ADA for the acceptance of peroxide-containing products published in 1994 require companies to demonstrate both safety and efficacy in a number of ways.[4] Currently there are three bleaching products with 10% carbamide peroxide bleaching agents that have received the ADA seal of approval after several clinical studies demonstrating their clinical safety and efficacy. However, there was no report demonstrating quantitative initial color changes. This study compared the efficacy of two of these 10% carbamide peroxide bleaching systems—Nite White and Opalescence—using a spectrophotometer for accurate color measurements.

The distribution of ΔL*, Δa*, and Δb* obtained in this study indicated that both bleaching systems increased L* values while decreasing the a* and b* values. The baseline prebleaching color for the two groups indicated similar color distributions (see Figure 2) with no statistically significant differences. Therefore, it may be argued that the bleaching systems appeared to have similar optical effects on tooth color changes at the area examined in this study. In contrast, the distributions of ΔL*, Δa*, and Δb* with Nite White were wider than those obtained using Opalescence on the central incisors and the canines. Furthermore, the mean ΔE value of Nite White was slightly higher than that of Opalescence. This suggests that Nite White indicated greater effects compared with Opalescence, although none of the differences calculated were statistically significant.

Color difference values with regard to clinical acceptability have been discussed, and ΔE of < 3.6 is considered a clinically acceptable color difference.[26] The mean ΔE values obtained for the canines and central incisors by both systems were > 3.6, indicating clinically distinguishable color change. However, the smallest ΔE values for Nite White were 1.62 for the central incisor and 0.4 for the canine as opposed to 2.18 for the central incisor with Opalescence. This indicated that some teeth had no color changes that could be recognized perceptively. Whereas the optical change achieved with Nite White was greater, SDs of the mean ΔE values were 1.5 times higher for Nite White in comparison with Opalescence.

As the two systems were not applied on the same subjects, results cannot be compared directly. Even so, the two groups did present a similar baseline prebleaching color distribution without a statistically

significant difference for the mean L*, a*, and b* values. This statistically similar starting point may allow us to infer that the Opalescence system offers better predictability.

Possible explanations for the findings of this study are the difference in viscosity of the bleaching agents and the presence/absence of small reservoirs provided in the bleaching trays used in combination with Opalescence. The purpose of the custom tray is to keep the bleaching gel in contact with the tooth. The advantage of the reservoirs lies in avoiding pressure on teeth and in allowing optimal tray seating despite the presence of a highly viscous material. In addition, the custom tray with a reservoir is supposed to better prevent leakage of solution onto the soft tissues that could lead to gingival irritation. The available information in the related literature remains inconclusive. One study found for instance that successful bleaching occurred beyond the borders of trays that had been cut too short inadvertently in the cervical tooth regions.[27]

With regard to sensitivity, 39.88% of subjects for Opalescence and 41.37% for Nite White reported a slight (mean score was < 0.8), reversible sensitivity. The difference was, however, not statistically significant. Sensitivity is the main side effect of tooth bleaching, and it has been reported that it is independent of age, sex, tooth characteristics, and dental arch.[28] The amount and quality of pain reported in this study varied between individuals. Since many of the subjects included in this study were dental professionals, we considered that the level of understanding of the involved procedures and the reporting accuracy of possible tooth sensitivity during treatment was higher than the norm.

CONCLUSIONS

This study examined color changes obtained with two commonly used tooth-bleaching systems containing a 10% carbamide peroxide solution by spectrophotometric investigation. It was concluded that both systems led to distinguishable tooth color changes, with ΔE values over 3.6, which is consistent with a clinically noticeable color change. There were no statistically significant differences between the two systems as expressed by ΔE, ΔL^*, Δa^*, and Δb^*.

DISCLOSURE

The authors do not have any financial interest in the companies whose materials are discussed in this article.

REFERENCES

1. Harlan AW. Hydrogen dioxide. ADA Trans 1882: 70–93.
2. Westlake A. Bleaching teeth by electricity. Am J Dent Sci 1895; 29:101.
3. Haywood VB, Heymann HO. Nightguard vital bleaching. Quintessence Int 1989; 20:173–176.
4. Council on Dental Therapeutics. Guidelines for the acceptance of peroxide containing oral hygiene products. J Am Dent Assoc 1994; 125:1140–1142.
5. Li Y. Biological properties of peroxide-containing tooth whiteners. Food Chem Toxicol 1996; 34:887–904.
6. Russell CM, Dickinson GL, Jonson MH, et al. Dentist-supervised home bleaching with the percent carbamide peroxide gel: a six-month study. J Esthet Dent 1996; 8:177–182.
7. Haywood VB, Leonard RH, Nelson CF, Brunson WD. Effectiveness, side effects and long-term status of nightguard vital bleaching. J Am Dent Assoc 1994; 125:1219–1226.
8. Nathoo SA, Chmielewski MB, Kirkup RE. Effects of Colgate Platinum Professional Tooth Whitening System on microhardness of enamel, dentin and composite resins. Compend Contin Educ Dent 1994; 17:s627–s630.
9. Schulte JR, Morrissette DB, Gasior EJ, Czajewski MV. The effects of bleaching application time on the dental pulp. J Am Dent Assoc 1994; 125:1330–1335.
10. Kihn PW, Barnes DM, Romberg E. A clinical evaluation of 10 percent vs. 15 percent. J Am Dent Assoc 2000; 131: 1478–1483.
11. Matis BA, Cochran MA, Eckert G, Carlson TJ. The efficacy and safety of a 10% carbamide peroxide bleaching gel. Quintessence International 1998; 9:555–562.
12. Swift EJ, May K, Wilder AD, Heymann HO, Bayne SC. Two-year clinical evaluation of tooth whitening using an at-home bleaching system. J Esthet Dent 1999; 11:36–42.
13. Maccaslin AJ, Haywood VB, Potter BJ, Dickinson GL, Russel CM. Assessing dentin color changes from nightguard vital bleaching. J Am Dent Assoc 1999; 130:1485–1490.
14. Preston JD. Current status of shade selection and color matching. Quintessence International 1985; 16:47–58.
15. Millar L. Organizing color in dentistry. J Am Dent Assoc 1987; 115:26e–40e.
16. Sproull RC. Color matching in dentistry, part 1: the three-dimensional nature color. J Prosthet Dent 1973; 29: 416–424.
17. Ribino, Garcia A, Jimenez del Barco B, Romeno J. Colour measurement of human teeth and evaluation of colour guide. Color Res Appl 1994; 19:19–22.
18. O'Brien WJ, Boenke KM, Groh C. Coverage

errors of two shade guides. Int J Prosthodont 1991; 4:45–50.

19. Gerlach RW, Gibb RD, Sagel PA. Initial color change and color retention with a hydrogen peroxide bleaching strip. Am J Dent 2002; 15:3–7.

20. Gerlach RW, Barker ML, Sagel PA. Comparative efficacy and tolerability of two direct-to-consumer tooth whitening systems. Am J Dent 2001; 14:267–272.

21. Johnston WM, Hesse NS, Davis BK. Analysis of edge-losses in reflectance measurements of pigmented maxillofacial elastomer. J Dent Res 1996; 75:752–760.

22. Ishikawa-Nagai S, Sato S, Ishibashi K. Using a computer color matching system in color reproduction of porcelain restoration, part 3: a newly developed spectrophotometer designed for clinical application. Int J Prosthodont 1994; 7: 50–55.

23. Paravina RD, Power JM, Fay RM. Color comparison of two shade guides. Int J Prosthodont 2002; 15:73–78.

24. Hasegawa A, Ikeda I, Kawaguchi S. Color and translucency of in vivo natural central incisors. J Prosthet Dent 2000; 83: 418–423.

25. Bailey RW, Christen AG. Bleaching of vital teeth stained with endemic dental fluorosis. Oral Surg Oral Med Oral Pathol 1968; 26:871–878.

26. Johnston WM, Kao EC. Assessment of appearance match by visual observation and clinical colorimetry. J Dent Res 1989; 68:819–822.

27. Oliver TL, Haywood V. Efficacy of nightguard vital bleaching technique beyond the borders of a shortened tray. J Esthet Dent 1999; 11:95–102.

28. Leonard RH, Haywood VB, Phillips C. Risk factors for developing tooth sensitivity and gingival irritation associated with nightguard vital bleaching. J Esthet Dent 1997; 28:527–534.

Presented at the 70th International Association of Dental Research meeting, Gothenburg, Sweden, June 29, 2003.

Reprint requests: Shigemi Ishikawa-Nagai, Department of Restorative Dentistry and Biomaterials Sciences, Harvard School of Dental Medicine, 188 Longwood Avenue, Boston, MA, USA 02115; e-mail: shigemi_nagai@hsdm.harvard.edu

COMMENTARY

COMPARISON OF EFFECTIVENESS OF TWO 10% CARBAMIDE PEROXIDE TOOTH-BLEACHING SYSTEMS USING SPECTROPHOTOMETRIC MEASUREMENTS

Van B. Haywood, DMD*

The authors have addressed the question of determining which of two popular 10% carbamide peroxide bleaching materials is better, comparing one from Ultradent Products and one from Discus Dental. They have also addressed the problem that because shade tabs are nonlinear, they are not designed to determine color change but to match color.[1] To form a better comparison of the two products, the authors have used a spectrophotometer. Their results demonstrate that there is no difference between the two products. However, there are some subtle, additional insights to gain from this article.

One tray system used reservoirs and one did not, and there was no difference between the lightening effects. Although these are slightly different products, this result does support previous publications that state that reservoirs make no difference in lightening efficacy.[2–4] Generally reservoirs in trays were designed to reduce sensitivity by reducing the tight fit of the tray. However, in this study there was no significant difference in sensitivity scores, although the tray with the reservoir resulted in a slightly less frequency of sensitivity (39 vs 41%). Both tray designs were scalloped, so there is no comparison on gingival irritation.

It is also important to note that not all teeth had a visible color change. This observation reinforces that the dentist should not promise the patient a certain amount of color change as that change varies from patient to patient and tooth to tooth.

There are some concerns with the study design. Both of the products tested are designed for nighttime wear, but the authors only used them for only 4 h/d. Other studies would indicate that there is active material remaining even up to

Professor, Department of Oral Rehabilitation, Medical College of Georgia School of Dentistry, Augusta, GA, USA