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In Vitro Evaluation of Tooth-color Change Using Four Paint-on Tooth Whiteners

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Clinical Relevance

The results of this study indicate that Crest Night Effects and Colgate Simply White Night achieve a statistically significant mean number of visual shade changes and mean ΔE*ab Colorimeter readings.

SUMMARY

The effectiveness of four paint-on tooth whiteners was evaluated and compared in this *in vitro* study. Sixty extracted anterior teeth were selected and randomly assigned to five groups: 1–(AS) Artificial Saliva (Roxane); 2–(MSW) Sparkling White (Meijer); 3–(CNE) Crest Night Effects (Procter & Gamble); 4–(ABB) Beautifully Bright (Avon) and 5–(CSWN) Simply White Night Gel (Colgate-Palmolive). The teeth were cleaned with a soft bristle toothbrush and toothpaste (Procter & Gamble) to remove any residue from the storage solution. The bleaching gels were painted onto the surface of the teeth, and they were then wrapped in gauze moistened with artificial saliva and kept in 100% humidity at 98°F in a laboratory oven (Precision Scientific model 18EG) for 24 hours. The treatment was repeated once a day for 14 days. Visual color assessment was done using a value-oriented Vitapan Classical Shade Guide (Vident) and a colorimeter (Minolta Chroma Meter CR 321). PVS jigs (Exaflex, GC America) were fabricated for each tooth. Visual and colorimetric readings were recorded at baseline, 7 and 14 days. One-way ANOVA and Tukey multiple comparisons test were used to assess differences between groups. CNE and CSWN presented the highest mean number of shade changes and ΔE*ab Colorimeter readings. ABB and MSW did not significantly lighten the teeth, as measured

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by either method of evaluation after two weeks of the bleaching regimen.

INTRODUCTION

Esthetic dentistry dates back to the late 1800s, when it was very common to alter the shape of front teeth as well as to lighten them.[1] Tooth bleaching is one of the simplest, most commonly used esthetic enhancement techniques. Many different tooth-bleaching options are available to the patient: in-office, customized tray-delivery home bleaching and over-the-counter bleaching systems, such as strips, dentifrices, paint-on gels and generic tray-delivered materials.

Novel over-the-counter whitening systems are constantly being introduced to the market, generally at a much lower cost to the patient than the conventional dentist-prescribed procedures. The most recent whitening agents to be introduced are barrier-free, brush-applied systems.[2] The technology for these products allows the active ingredient (carbamide peroxide or hydrogen peroxide) to be incorporated into a suspension that is brushed onto the tooth surface, which adheres to enamel, without the use of a physical barrier.[2-5] To some consumers, this is convenient, because they can get the benefit of tooth whitening without wearing a tray or going to their dentist's office, and the cost of these whitening systems is much less than any other available technique.

A number of studies have been done to establish the safety and efficacy of older whitening products, such as tray-delivered materials, whitening dentifrices and bleaching strips.[1-2,6-8] However, paint-on whiteners are relatively new and have yet to establish their role as an effective tooth-whitening method that is readily available in today's market. Some paint-on tooth whiteners are unique, because they contain higher concentrations of whitening agents compared to whitening strips and tray-delivered materials that are available over-the-counter.

Research has shown that the oxidizing action of hydrogen peroxide is responsible for removing stains on teeth, and it has also been implicated in causing changes in the chemical composition and crystalline structure of enamel.[9-10] A loss of calcium and phosphate from enamel, along with a decrease in enamel microhardness, has been seen.[9-13] Hydrogen peroxide has the potential to cause damage to soft tissues, which is also a concern when dealing with a barrier-free delivery system in the mouth.[14-15] The extent to which these changes occur is relative to the duration of contact time and concentration of hydrogen peroxide in the whitening product.

Many studies have evaluated the efficacy of strip-delivered whitening systems and in-office whitening systems. In a clinical trial comparing the mean Δb* and ΔL* of 10% and 6% hydrogen peroxide whitening strips to baseline, it was found that both kinds of strips significantly whitened the teeth by the end of treatment. The mean Δb* for the 6% hydrogen peroxide strips was -2.49 (± 0.167) at day 15, while for the 10% strips, it was -3.31 (± 0.182), and the mean ΔL* at day 15 for the 6% strips and the 10% strips, respectively, was 2.35 (± 0.177) and 3.03 (± 0.194).[16] A similar *in vivo* study found that 6% whitening strips achieved a mean ΔE*ab of 3.79 (± 0.325) after 14 days of treatment.[17]

It has been demonstrated that the use of higher peroxide concentrations in whitening systems contributes to a faster or greater whitening response.[2,6] This study compared the effectiveness of four paint-on tooth whiteners.

METHODS AND MATERIALS

This *in vitro* study used 60 extracted human maxillary central and lateral incisors, shade A3 or darker. Any teeth with restorations, fluorosis, tetracycline staining, decay or other intrinsic staining were excluded. The teeth were kept in sodium azide solution prior to starting the study and artificial saliva solution (Roxane Laboratories, Columbus, OH, USA) during the study. The 60 teeth were randomly divided into five groups (Table 1).

The whitening treatments of the specimens followed manufacturers' guidelines. However, the protocol was altered slightly for ABB (the manufacturer recommended application was twice a day for one week. Instead, the gel was applied once a day for two weeks) to conform with the other four groups.

Prior to bleaching, two methods were used to record the baseline color for each tooth: visual and colorimeter. Visual color assessment was done independently by two examiners using a Vitapan Classical shade guide (Vident, Bad Sackingen, Germany). The Vita shade guide was arranged in value order, and each shade was given a number between 1 and 16, with 1 being the highest value and 16 being the lowest. Prior to recording the actual readings, the two evaluators were cali-

Table 1: *Treatment Assignments*

Group	Treatment Product	Active Ingredient	% Hydrogen Peroxide
AS	Artificial Saliva	Control	0%
MSW	Meijer Sparkling White Whitening Gel	10% Carbamide Peroxide	3%
CNE	Crest Night Effects	19% Sodium Percarbonate	6.3%
ABB	Avon Beautifully Bright	Urea Peroxide	Not provided
CSWN	Colgate Simply White Night Whitening Gel	8.7% Hydrogen Peroxide	8.7%

Figure 1: *Minolta Chroma Meter CR321 with PVS jig and sample tooth in place.*

brated by individually looking at 10 teeth under color corrected lights and assigning Vita shades. The results were compared and any disagreements discussed until a concensus agreement was reached and recorded. A similar process was adopted for reading the actual samples. All shade determination was done in a blinded fashion.

The baseline tooth color was also determined with a colorimeter (Minolta Chroma Meter CR321, Osaka, Japan). Individual Extrude PVS (Kerr Inc, Orange, CA, USA) jigs were fabricated for each tooth using a replica of the colorimeter head (Figure 1). The jigs ensured that the position of the tooth relative to the colorimeter head was the same for each color measurement. The colorimeter used monochromatic light to measure the reflectance curve of the test sample and provided L*, a* and b* values. The L* scale represented the lightness or grayness of the specimen. The a* scale represented the red-green chromaticity difference, while the b* scale measured the yellow-blue chromaticity difference. The point where a* and b* intersected was the true color of the specimen. From this data, the ΔE*ab value was calculated according to the following formula:

$$\Delta E^*ab = \sqrt{(\Delta l^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

The total color contrast between the original reading and the bleached test specimen is represented by ΔE*ab. Before testing the specimens, the Chroma Meter CR321 was calibrated using a standard white reflector plate. The Minolta Data Processor DP-100 (Minolta, Osaka, Japan) was used to collect, store and print the data.

Once baseline color values were obtained for each tooth, they were brushed with toothpaste (Crest Cavity Protection Sparkle Fun, Procter & Gamble, Cincinnati, OH, USA) and water with a soft-bristled toothbrush and rinsed thoroughly. The teeth were wrapped in gauze impregnated with artificial saliva solution (Roxane Laboratories), placed in an individual re-sealable plastic bag and stored in an oven (Precision Scientific model 18EG) set at 98 ± 1 degrees Fahrenheit. At the beginning of the bleaching segment, each tooth was brushed with a toothbrush using only water and dried thoroughly with a paper towel. A single layer of bleach was painted on the facial, mesial and distal surfaces, with the bleach specified for each respective group. The bleach was allowed to dry for 30-60 seconds before wrapping the teeth in the gauze and placing them back in the re-sealable plastic bag. Additional artificial saliva was added as needed to keep the teeth moist. The labeled bags were then placed in the oven at 98 ± 1 degrees Fahrenheit between applications. This process was repeated once a day for 14 days. Using the Vita Classic shade guide, color assessment was done independently by two examiners at 7 and 14 days. Consensus agreements were again recorded. Colorimeter readings were also taken for each tooth at 7 and 14 days. After the two week period, the Mean Visual shade change was calculated, along with the Mean ΔE*ab, Δb* and ΔL* readings from the colorimeter. ANOVA and Tukey analysis were done to determine statistical significance.

RESULTS

Table 2 shows the mean visual shade changes (± SD) for each group from baseline to 14 days. Relative to the control, CNE and CSWN showed significant ($p<0.05$) color whitening, with mean shade changes of 4.25 (± 2.70) and 4.58 (± 2.78), respectively. MSW and ABB, however, did not show significant color whitening relative to the control after two weeks of the bleaching regimen. These results are in agreement with the mean ΔE*ab colorimeter values that were calculated comparing two-week values to the control (Table 3). Both CNE 5.60 (± 1.84) and CSWN 5.50 (± 2.15) showed statistically significant color change ($p<0.05$), while MSW and ABB did not show statistically significant color change at 14 days.

Table 2: *Mean Visual Shade Changes from Baseline to Day 14*

Product	Mean Visual Shade (±SD)	Sig*
AS	0.58 (± 1.00)	A
MSW	2.58 (± 2.35)	A B
ABB	3.08 (± 2.61)	A B
CNE	4.25 (± 2.70)	B
CSWN	4.58 (± 2.78)	B

**Means with the same letter are not significantly different at p<0.05.*

Table 3: *Mean ΔE*ab Values from Baseline to Days 7 and 14*

Product	N	Mean ΔE*ab Baseline–Day 7	Sig*	Mean ΔE*ab Baseline–Day 14	Sig*
CSWN	12	5.73 (± 3.19)	A	5.50 (± 2.15)	A
CNE	12	4.96 (± 2.18)	A B	5.60 (± 1.84)	A
MSW	12	4.36 (± 2.18)	A B	3.80 (± 1.81)	A B
ABB	12	3.22 (± 1.31)	A B	4.37 (± 1.89)	A B
AS	12	2.43 (± 1.65)	B	2.86 (± 1.55)	B

*Means with the same letter are not significantly different at p<0.05.

Table 4: *Mean Δb* from Baseline to Day 14*

Product	N	Mean Δb* Baseline–Day 14	Sig*
AS	12	0.50 (± 0.82)	A
ABB	12	-0.14 (± 0.99)	A B
CNE	12	-0.36 (± 1.18)	A B
MSW	12	-0.38 (± 1.62)	A B
CSWN	12	-1.54 (± 2.54)	B

*Means with the same letter are not significantly different at alpha <0.05.

Table 5: *Mean ΔL* from Baseline to Day 14*

Product	N	Mean ΔL* Baseline–Day 14	Sig*
CNE	12	5.02 (± 2.44)	A
ABB	12	4.01 (± 2.03)	A B
CSWN	12	2.84 (± 4.24)	A B
MSW	12	2.09 (± 3.10)	A B
AS	12	1.41 (± 2.75)	B

*Means with the same letter are not significantly different at alpha <0.05.

Table 4 shows the mean Δb* values comparing two-week colorimeter readings to baseline. CSWN showed the only significant decrease in yellowness at $p<0.05$, -1.54 (±2.54). The other groups did not show any significant decrease in yellowness relative to the control.

Table 5 shows the mean ΔL* colorimeter values, comparing two-week readings to the control. After two weeks of treatment, CNE, 5.02 (± 2.44) was the only group to show a significant increase in lightening of the teeth.

DISCUSSION

This study compared the effectiveness of four paint-on tooth whiteners and determined their whitening effect on the enamel surface. With regards to this study, it is worth noting that the mean ΔE*ab values for CNE at the end of one week had not significantly increased (4.96), but at the end of two weeks of treatment, they increased significantly compared to the control readings (5.60). However, CSWN (5.73) showed a significant ΔE*ab after one week of treatment relative to the control, and it maintained a significant mean ΔE*ab at the end of two weeks, with a slight decrease in ΔE*ab value (5.50).

It has been reported that the Δb* parameter plays an important role in aging-related, intrinsic tooth discoloration and self-perceived tooth whitening.[7,12] In this study, CSWN was the only group to show a significant decrease in yellowness. A previous study by Barlow and others[3] showed CNE had a significant mean Δb* of -1.43 after two weeks of treatment. However, the current study did not reflect these findings.

While both CNE and CSWN reached significant visual mean shade changes, as well as significant mean ΔE*ab colorimeter values, only CNE showed a significant increase in mean ΔL*, which represents an increase in lightness of the tooth, and only CSWN showed a significant decrease in mean Δb*, which represents a decrease in yellowness of the tooth. This is worth noting, because it demonstrates that both values are important in determining the mean ΔE*ab, a measure of overall color change of the tooth.

With the results showing that two of the whitening systems did not significantly whiten the teeth, while two systems were successful, it would be worth knowing the percentages of active whitening agents in each system; unfortunately, this information was not available from one of the manufacturers (Table 1).

It is possible that the technique of keeping the teeth wrapped in artificial saliva-soaked gauze used by the authors of this study may have induced some dilution or rubbing effects. However, it is more likely that this is closer to being an ideal scenario when compared to the actual oral environment in which dilution and rubbing effects would occur to a greater extent. Therefore, the results of this study may be an overestimation of the efficacy of these products.

Many studies have been conducted to evaluate the efficacy of strip-delivered and in-office whitening systems. In a clinical trial comparing the mean Δb* and ΔL* of 10% and 6% hydrogen peroxide whitening strips as compared to baseline, it was found that both systems significantly whitened teeth by the end of treatment. The mean Δb* for the 6% hydrogen peroxide strips was -2.49 (± 0.167) at day 15, while for the 10% strips, it was -3.31 (± 0.182), and the mean ΔL* at day 15 for the 6% and 10% strips, respectively, was 2.35 (± 0.177) and 3.03 (± 0.194).[16] A similar *in vivo* study found that 6% whitening strips achieved a mean ΔE*ab of 3.79 (±0.325) after 14 days of treatment.[17] Both of these values show a greater decrease in yel-

lowness than all of the paint-on whiteners used in the current study.

Finally, that same study found mean ΔL* values for 6% and 10% hydrogen peroxide strips to be 2.35 (± 0.177) and 3.03 (± 0.194), respectively.[16] The mean ΔL* value for the 6% hydrogen peroxide strips was higher than the ΔL* value found for the MSW paint-on whitener in this study, but it was lower than the mean ΔL* values found for the CSWN, ABB and CNE groups. The mean ΔL* value for the 10% hydrogen peroxide strips was higher than CSWN and MSW but lower than CNE and ABB. One aspect worth noting when comparing these studies is that the studies that tested the efficacy of the whitening strips were done *in vivo*, while the current study was conducted *in vitro*. This factor contributes to the variation in results found in the literature.

Another aspect of these paint-on tooth whiteners that should be addressed in future studies are the effects of the bleaching agents on the soft tissues of the oral cavity and the GI tract.[14-15] These products offer ease of application and the comfort of a barrier-free delivery system. However, they also subject the soft tissues to direct contact with a known carcinogenic substance without the supervision of a dentist. Also, the whitening agents are in direct contact with saliva, which is swallowed, and it is important to address the potential for frequent users to suffer an upset stomach if the material is swallowed. This is why it is very important to determine how these barrier-free whitening systems can affect all body tissues with which they have contact.

CONCLUSIONS

Within the limitations of the current study, the authors conclude:

1. CNE and CSWN presented the higher mean number of shade changes and higher mean ΔE*ab Colorimeter readings. With both methods of evaluation, CNE and CSWN were significantly different from the control.
2. ABB and MSW paint-on whiteners did not significantly lighten teeth after two weeks of a bleaching regimen, as measured with either method of evaluation.

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