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Extended Bleaching of Tetracycline-stained Teeth: A 5-Year Study

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Clinical Relevance

When using a tray delivery technique, tetracycline-stained teeth can be effectively lightened with the extended use of tooth whiteners. Cervical staining is the most difficult area to lighten.

SUMMARY

Bleaching tetracycline-stained teeth is the most challenging form of tooth lightening. This article reports on 44 subjects who bleached their tetracycline-stained teeth for 6 months using trays with reservoirs overnight in a half-mouth designed study and 2 of 3 different concentrations of carbamide peroxide (10%, 15% or 20%). The subjects were followed for 5 years. The area

evaluated was the middle third of the teeth. More than 55% of tooth lightening occurred within 1 month; after 5 years, more than 65% of the maximum tooth whitening remained for all 3 gel concentrations. Tooth whitening can be accomplished with any of the 3 concentrations used.

INTRODUCTION

Bleaching has been universally accepted as a method of lightening discolored teeth. Some practitioners, however, continue to question the efficacy of vital tooth bleaching on more severely intrinsic stains, such as those caused by systemic ingestion of tetracycline and fluoride.

When bleaching tetracycline-stained teeth, Haywood, Leonard and Dickinson,¹ in 1997, were the first to show that using carbamide peroxide (CP) applied in trays and used overnight can be effective. Since then, another study has reported on tetracycline-stained teeth bleached in-office and/or CP², while a third study compared hydrogen peroxide and CP³. Nine-month and 2-year reports of the current study have already been published.^{4,5} A 90 month follow-up of Haywood's 1997 study has been published and documents the effectiveness of tray bleaching in reducing discoloration for an extended period of time.⁶

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The current research is a 5-year study that reports the effects of bleaching using 2 of 3 different bleaching concentrations for a 6-month period. The concentrations were 10%, 15% and 20% CP. They were used overnight in a tray with reservoirs.

Most tetracycline stained teeth are darker than the darkest shade guides available to the profession. This study quantified the change in all parameters of color, therefore, 4 additional shade guide tabs were prepared for use. By quantifying changes, the researchers were able to statistically analyze the data.

This study was accomplished at the Wuhan University School of Stomatology in the People's Republic of China. The protocol was approved by the Institutional Review Board at Indiana University-Purdue University Indianapolis (Indianapolis, IN, USA).

METHODS AND MATERIALS

Subjects who responded to the posted notices had to meet certain inclusion/exclusion criteria (Table 1). A Loe and Silness gingival index⁷ was utilized to ensure that subjects did not have moderate or severe periodontal tissue inflammation.

Those who met the criteria for entry into the study had alginate impressions taken of their maxillary arches. In the model, a reservoir (LC Block Out Resin, Ultradent Products, Inc, South Jordan, UT, USA) was placed on the buccal surfaces of the anterior and bicuspid teeth, which extended to the incisal/occlusal surfaces but was 1 millimeter short of the mesial, distal and cervical surfaces of the teeth. A custom maxillary arch tray (Sof-Tray, Ultradent Products Inc) was fabricated for each subject.

Subjects returned for a dental prophylaxis at least 1 week before baseline to remove any extrinsic stains. This also allowed for any inflammation from the dental prophylaxis to resolve, so that baseline color could be more accurately assessed.

At baseline evaluation, subjects were randomly assigned to 1 of 6 groups in this split-mouth designed study. The subjects were assigned to 1 of 3 concentrations on the left side and a different concentration on the right. For 6 months, the subjects were instructed on how and on what side to use the bleaching

agents while sleeping. They were also given written directions on the procedures they were to follow. The use of different numbered syringes containing bleaching agents was discussed during the evaluations. Use of the differently numbered syringes occurred during the first 2 months to ensure that the subjects were using the appropriate concentrations on the correct sides. Subjects were not aware of the concentration of bleaching agent they were using

A color evaluation with an expanded shade guide which included shades C6 to C9 (Vitaescence Esthetic Restorative Masters Shade Guide, Ultradent Products, Inc) (Figure 1) were taken of all maxillary anterior teeth. The additional shades were made by mixing together filler particles in increasing proportions. Photographs were taken with Ectachrome Elite 100 35-mm film (Kodak, Rochester, NY, USA) using a Nikon

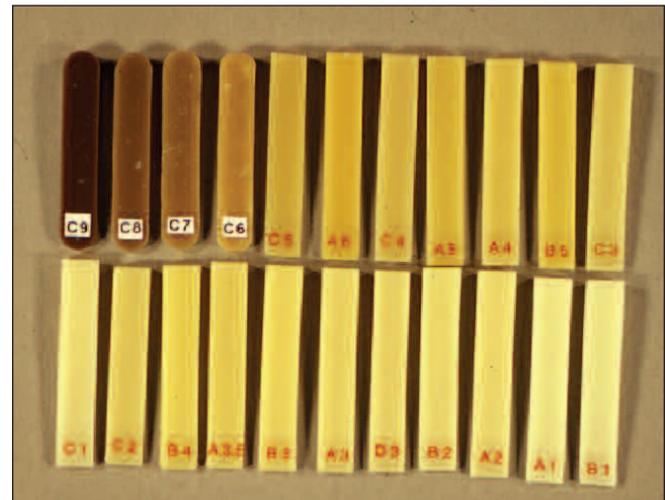


Figure 1: Vitaescence Esthetic Restorative Masters Shade Guide with C6-C9 shades included.

Table 1: Inclusion and Exclusion Criteria for Acceptance as Subjects

Inclusion Factors	
1	18 years of age
2	Willing to sign a consent form
3	Willing to return for periodic evaluations
4	Willing to refrain from tobacco use for first 9 months of study
5	Presence of 6 maxillary anterior teeth
6	No more than 1/6 of the facial surface of above teeth covered with restoration
7	Presence of tetracycline staining
Exclusion Factors	
1	Use of bleaching agents in past 3 years
2	Use of tobacco during previous 30 days
3	Loe and Silness Gingival score greater than 1
4	Study teeth lighter than A-3
5	History of disease that would interfere with study
6	Presence of gross pathology
7	Pregnant or lactating

camera (Model N6006, Tokyo, Japan) with a ring flash (Vivitar 550 FDN, Newbury, CA, USA) to document the color of the teeth at each evaluation appointment.

The color of each tab in the shade guide was evaluated with a colorimeter (Minolta, Chroma Meter CR-321, Tokyo, Japan) (Table 2). This determined comparable color spaces between all of the shades tabs, including those that were added. The colorimeter defines color in the internationally accepted CEILAB system.⁸ The total color difference was calculated using the E* value.

The subjects were informed that there could be some tooth or gingival sensitivity while using the products. When the subjects returned for their monthly evaluations, they were given a new sheet on which to list the maximum sensitivity experienced each day during active use of the product and during 1 month post-bleaching. The subjects were asked to rate their sensitivity experience in 1 of 5 categories: 1–no sensitivity, 2–slight sensitivity, 3–moderate sensitivity, 4–considerable sensitivity and 5–severe sensitivity. If the subjects experienced more than moderate sensitivity, they were to return to the clinic for some desensitizing gel (UltraEZ, Ultradent Products, Inc). If any of the subjects, after using the desensitizing gel, still experienced more than moderate sensitivity, they were given 10% CP gel or were asked to withdraw from the study. None of the subjects withdrew from the study due to more than moderate sensitivity.

The subjects returned for evaluations at 1 and 2 weeks, monthly for 9 months, then at 2 and 5 years subsequent to the start of the study. Shade guide determinations and photographs were taken at each evaluation appointment. ΔL^* , Δa^* , Δb^* and ΔE^* were computed by subtracting the baseline colorimeter measurements for the appropriate shade tabs from the follow-up measurements. Comparisons between products and examinations were made using ANOVA. The ANOVA models included effects for tooth type, product, examination and interactions between those effects and baseline L*, a* and b* as covariates. The ANOVAs also included terms that allowed for correlations between measurements on multiple teeth within a subject and correlations between multiple examinations of the same teeth. Pairwise comparisons between products were made using the Sidak adjustment method to control the overall significance level for the tests: adjusted p -value = $1 - (1 - \text{original } p\text{-value})^{\# \text{ of tests}}$. Comparisons were considered statistically significant if the p -value was less than 0.05 and identified as “marginally significant” if the p -value was between 0.05 and 0.10.

At the end of the 6-month evaluation, subjects were not given any additional gel and were instructed to refrain from using the tray. At the end of 9 months, due to ethical considerations, the subjects had a tray fabri-

cated for their mandibular arch and were encouraged to bleach their lower arch.

Subjects also filled out questionnaires at the 3- and 9-month evaluation appointments and at the 2- and 5-year evaluation appointments. These questionnaires were used to determine if any days of bleaching were missed and the subjects responses to bleaching. A more complete section on Methods and Materials can be found in a previous publication, which documented the first 9-month summary of this study.⁴

RESULTS

Of the 59 subjects who initially enrolled in the study, 44 completed the 5-year evaluation. That number represented 30, 28 and 30 half mouths of 10%, 15% and 20% CP, respectively. Of the 44 subjects who came in for the 5-year evaluation, 36 missed none of the 14 appointments, 5 missed 1 appointment, 1 missed 1 appointment and 2 missed 3 appointments.

There are 5 critical times in this study that will be highlighted from the results standpoint. These times are after the first and sixth month of bleaching, at 9 months (3 months post-bleaching) and at 2 and 5 years from initiating bleaching. At baseline, there were no differences in the parameters of color (Table 3).

Table 2: Colorimeter Readings in CIELAB for Vitaescence Restorative Masters Shade Guide and Added Shades of C6, C7, C8 and C9

Tab	L*	a*	b*
B1	64.27	-3.06	1.19
A1	63.89	-2.99	2.34
A2	59.95	-2.52	5.36
B2	59.65	-3.01	5.86
D3	58.99	-2.47	6.30
A3	57.16	-2.58	6.36
B3	56.23	-2.64	8.68
A3.5	54.40	-2.26	8.63
B4	53.80	-2.88	9.41
C2	54.13	-2.42	6.28
C1	54.00	-2.28	0.04
C3	52.90	-2.49	6.58
B5	51.71	-2.05	12.84
A4	52.31	-1.78	9.63
A5	48.84	-1.66	11.62
C4	49.27	-1.60	6.84
A6	44.45	-0.59	12.14
C5	43.30	-1.40	6.90
C6	40.41	0.39	9.25
C7	36.44	0.80	7.18
C8	33.15	1.47	6.67
C9	25.40	3.47	6.51

Table 3: Chroma Meter Values at Baseline, 1 Month, 6 Months, 9 Months, 2 Years and 5 Years

Time	10% (n=30)		15% (n=28)		20% (n=30)		
	Mean	SD	Mean	SD	Mean	SD	
L*	Baseline	41.06	2.87	39.69	2.28	39.95	2.69
	1 Month	49.53	4.30	48.82	5.12	50.18	5.45
	6 Months*	56.73	2.69	55.56	3.99	56.57	4.52
	9 Months**	54.70	2.94	53.86	4.17	54.62	4.42
	2 Years	54.46	2.74	53.79	4.10	54.73	4.39
	5 Years	51.91	3.41	50.44	4.59	51.03	4.08
a*	Baseline	-0.07	0.71	0.22	0.63	0.16	0.60
	1 Month	-1.61	0.51	-1.48	0.73	-1.63	0.77
	6 Months*	-2.47	0.28	-2.33	0.47	-2.44	0.41
	9 Months**	-2.31	0.38	-2.24	0.58	-2.30	0.57
	2 Years	-2.30	0.36	-2.25	0.58	-2.35	0.57
	5 Years	-2.11	0.42	-1.92	0.59	-1.95	0.49
b*	Baseline	8.51	1.01	8.28	0.84	8.37	1.11
	1 Month	8.15	1.67	8.60	1.59	8.03	2.11
	6 Months*	7.05	1.72	7.01	2.12	6.09	2.21
	9 Months**	8.56	1.97	8.35	1.73	7.96	1.57
	2 Years	8.73	1.92	8.52	1.69	7.95	1.54
	5 Years	8.51	1.57	7.87	1.40	8.00	1.42

*: 1 subject (10%/20%) missed the 6 month visit.
 **: 2 subjects (10%/20% and 10%/15%) missed the 9-month visit.

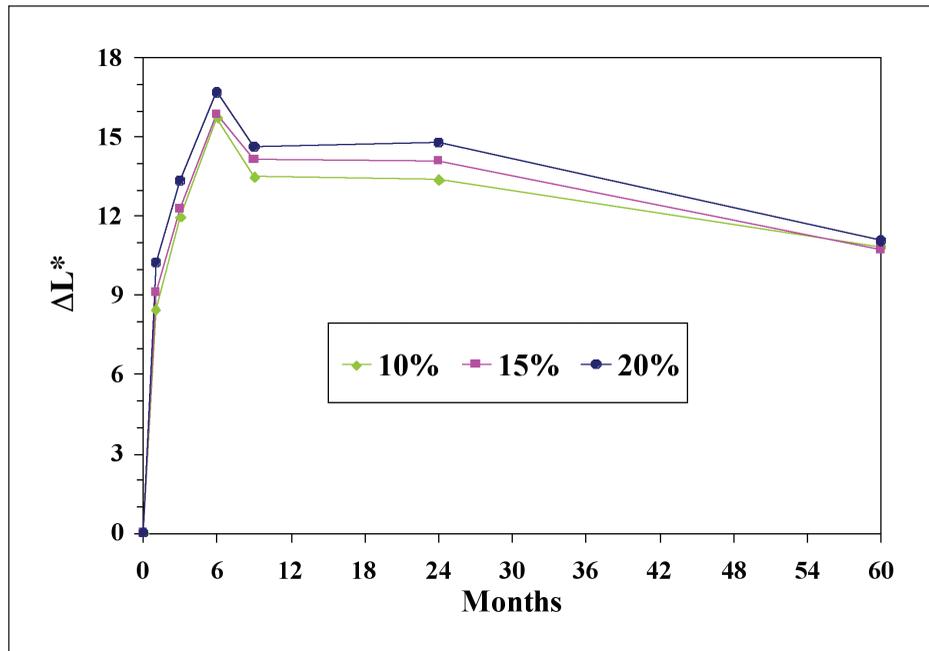


Figure 2: Delta L* for 10, 15 and 20% carbamide peroxide used in trays with reservoirs for 6 months.

Delta L*

L* represents value in color on the white-black spectrum. The 10% concentration was not statistically different in L* than the 15% concentration overall or at any of the evaluations; however, it was statistically different from the 20% concentration at all points except at 5

years. Fifteen percent was not statistically different from the 20% concentration at any of the 5 points in time (Figure 2).

Delta a*

Representing the red-green color spectrum is a*. The 10% concentration was not different in a* from that of the 15% concentration overall or at any of the 5 points in time, but it was marginally different from the 20% concentration at 4 weeks. The 15% concentration was not different from the 20% concentration at any time period (Figure 3).

Delta b*

Representing the yellow-blue color spectrum is b*. The 10% percent concentration in b* was not any different from the 15% concentration overall or at any of the points in time, but it was significantly different from the 20% concentration at 24 weeks, 36 weeks and 2 years. The 15% concentration was significantly different from the 20% concentration at 24 weeks but not at 4 weeks, 36 weeks, 2 years or 5 years (Figure 4).

Delta E*

Representing the difference in overall color is E*. The 10% concentration was not significantly different from the 15% concentration overall or at any of the time points, but it was different from the 20% concentration at 4 weeks, 24 weeks and 2 years. The 15% concentration was not significantly different from the 20% concentration at any of the 5 time periods (Figure 5).

Tooth and Gingival Sensitivities

The 10% concentration had significantly lower tooth sensitivity than the 15% and 20% concentrations. The 15% and 20% concentrations did not have significantly

different tooth sensitivity. The 10% and 15% concentrations did not have significantly different gingival sensitivity, but both had lower overall sensitivity compared to the 20% concentration.⁴ Five subjects (36%), 4 subjects (25%) and 6 subjects (43%) who used 10%/15%, 10%/20% and 15%/20% concentrations, respectively, requested desensitizing gel (Ultra-EZ, Ultradent Products Inc). Two subjects who used 15% concentration and 1 subject who used 20% concentration were lowered to 10% because of continued sensitivity.

Subject Responses

The questionnaire filled out by the subjects at the 3- and 9-month evaluation appointments indicated that 88% and 60% of the subjects were at least “pleased” and, at the 5-year evaluation appointment, 41% were at least “pleased” with how their “teeth look at the present time.” When asked how pleased they were with the way the “area closest to your gums bleached” at the 5-year evaluation, only 43% said they were “a little pleased” and 27% said they were “not pleased” (Table 4). At the 5-year evaluation, the authors of this study asked, “If your friend had tetracycline-stained teeth, like you did, would you recommend bleaching to your friend?” Ninety-one percent said they would recommend bleaching. Two of the 44 subjects said they would recommend that their friend “do nothing.”

On the 2-year questionnaire, the subjects were asked about bleaching their mandibular teeth. They were told that they could have any of the 3 concentrations of CP used during the study. Thirty percent said they did not want to bleach their mandibular teeth. Of those who chose to bleach, 22% (6) used 10%, 55% (15) used 15% and 22% (6) used 20% CP.

These subjects were informed that the gel would be provided to bleach their mandibular arches for as long as they desired. The mean time they bleached their mandibular teeth was 2 months 6 days. Only 5 of the

patients stated that their mandibular teeth lightened as much as their maxillary teeth. The mean time of bleaching for those who stated their mandibular teeth acquired the same lightness as their maxillary teeth was 3 months 10 days. All of the patients stated they had not used any whitening agents on their maxillary teeth after the initial 6 months of bleaching.⁴

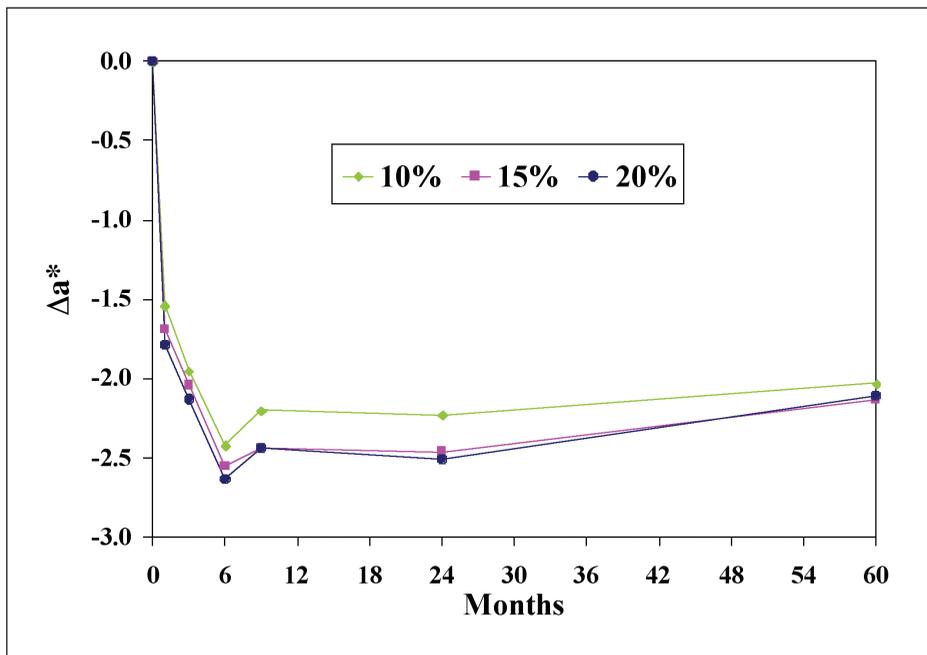


Figure 3: Delta a* for 10, 15 and 20% carbamide peroxide used in trays with reservoirs for 6 months.

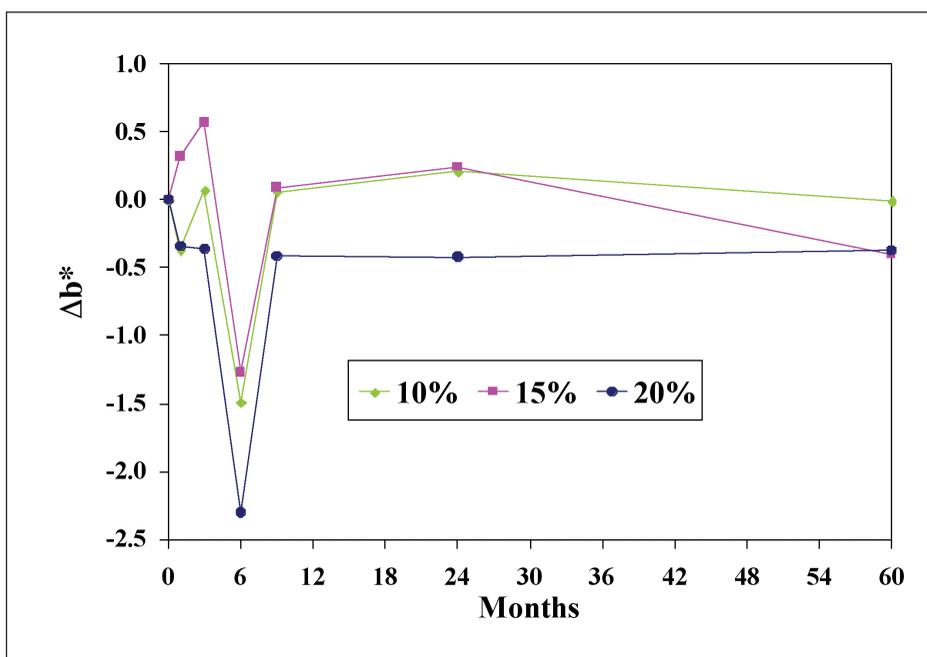


Figure 4: Delta b* for 10, 15 and 20% carbamide peroxide used in trays with reservoirs for 6 months.

DISCUSSION

Tetracycline is a very effective antibiotic; however, it is very rarely prescribed for children because of its staining potential to teeth. When treating patients who have tetracycline staining, it is important to ask if they have used tooth bleaching agents in the past. If so, and a further reduction in cervical staining is requested, it is important to inform them that the reduction in cervical staining is very slow and it will take an extended time to lighten the area. Dr Haywood has reported bleaching for up to a year to remove more of the cervical staining.⁹ It is reasonable to assume that, if the application of gels had been continued beyond 6 months, then the teeth would have continued to lighten, with the eventual outcome being that those teeth bleached with the 10% gel

would become as light as those teeth bleached with the 20% gel.

This study is the first of its kind to be conducted on subjects without access to tooth whiteners. This is important, because, where tooth-whitening agents are available, some individuals with tetracycline-stained teeth may have used tooth whiteners in the past. The bleaching of such subjects requires a much different strategy. Subjects who are accepted into tetracycline-staining studies and who are attempting to lighten their teeth should be excluded from a study if they have previously used any tooth-whitening agents.

The cervical areas of tetracycline-stained teeth are very slow to respond to whitening agents and may take at least a year of overnight use to reduce the staining to acceptable levels. A high percentage of subjects in this study were not pleased with the cervical loss of staining 5 years after initiating bleaching.

In this study, tooth bleaching of tetracycline-stained teeth was shown to occur very rapidly in some areas of the teeth. Some studies have indicated that minimal bleaching occurs during the first 2 to 6 weeks.¹⁻² This might account for the fact that the shade guides that were used only go to C4 as the darkest shade. In this study, 4 shades darker than C5 were made available.

When assessing colors, previous studies have been limited because of the lack of darker shade tabs in the shade guide. In one study, 16 of the 21 baseline values were C4 or greater on the Vita Classic shade guide.⁶ The other 2 studies reporting the lightening of tetracycline stains required a C4+ designation, indicating that the shades of teeth were darker than C4.²⁻³ In this study, 41 (91%) of the 44 subjects had all 6 teeth in the C5-C9 range at baseline. Only 6 out of the 264 teeth in this study, at baseline, were shade C4 or lighter.

The darkest portion of the tooth, from the middle third, was used for shade evaluation. The total change in color, represented by delta E*, changed more in the first

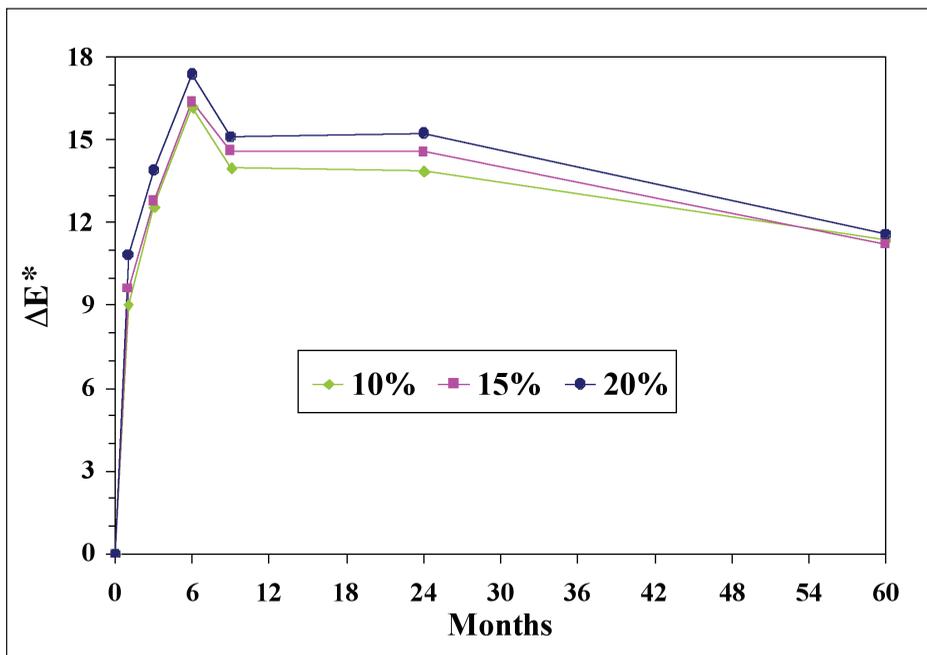


Figure 5: Delta E* for 10, 15 and 20% carbamide peroxide used in trays with reservoirs for 6 months.

Question	Responses	10%/15%	10%/20%	15%/20%	Total
How pleased are you with how your teeth look at the present time?					
	Very, very pleased	7	0	7	5
	Very pleased	14	14	0	9
	Pleased	29	31	21	27
	A little pleased	43	31	64	45
	Not pleased	7	25	7	14
How pleased are you with the way the area closest to your gums bleached?					
	Very, very pleased	7	0	7	5
	Very pleased	0	6	0	2
	Pleased	36	25	7	23
	A little pleased	43	38	50	43
	Not pleased	14	31	36	27



Figure 6: Subject #21 used 15% on the right side and 10% on the left side. This subject used 15% on the lower arch for 3 months and felt the lower arch become the same lightness as the maxillary teeth. Shades reported are of the middle third of the maxillary right and left centrals, respectively: A=Baseline C5/C5, B=1 month: A4/C4, C=6 months: A3/A3, D=3 months postbleaching: A4/A4. Figures A-D reprinted with permission of Quintessence Publishing Co, Inc.



Figure 7: Subject #43 used 10% on the right side and 20% on the left side. This subject used 10% on the lower arch for 3 months and felt that the lower arch did not become as light as the maxillary teeth. Shades reported of the middle third of the maxillary right and left centrals, respectively: A=Baseline C7/C7, B=1 month: C6/C5, C=6 months: B4/B3, D=3 months postbleaching: A4/A3.5, E=1.5 years postbleaching: A4/A4, F=4.5 years postbleaching: C5/C5. Figures A-D reprinted with permission of Quintessence Publishing Co, Inc.

month than in the following 5 months. Ten percent concentration attained 55%, 15% concentration attained 58% and 20% concentration attained 62% of the maximum change at the end of 1 month compared to what was attained during the entire 6 months of bleaching. At the 5-year evaluation time point of delta E, the 10%, 15% and 20% concentrations had retained 68%, 67% and 66% of the total color, respectively.

A previous publication identified 4 different categories of tetracycline staining, which were evident in this study.⁴ The categories that were most likely to produce an excellent result were those where tetracycline staining was homogenous, concentrated in the incisal two-thirds of the tooth or where banding was evident. The category of tetracycline staining that did not respond well to bleaching was where the staining was in the cervical area. Examples of categories and their changes can be seen in the presentation of 4 subjects at baseline, 1 month and 6 months of bleaching and at 3 months, 1.5 years and 4.5 years post-bleaching (Figures 6-9).

The unexpected change in b^* is due to 2 factors. One is the very low value of shade C1. It was measured in triplicate and remeasured in triplicate, and it did not vary from the value of 0.04. The second factor is the tendency for the b^* value to increase as the color of

shade guide tabs decreases. This was not the case, however, as the darkest 5 shade tabs were less dense in b^* than the next 5 darker shade tabs.

Subjects in this study reported comparable sensitivity, as has been reported in other studies.¹⁰ Those subjects who used the lowest concentrations of CP reported significantly less tooth sensitivity in those areas compared to the sides in which they used the higher concentration of CP. Those subjects whose concentration was lowered to the 10% concentration continued bleaching with the new concentration to the end of the study; however, for statistical purposes, they were kept at the sensitivity levels that they were at when they switched concentrations.

This is the first study to document that there is a reversal of color change in tetracycline-stained teeth. It appears that those who bleach to remove stain caused from tetracycline will need to re-bleach within 5 years. There is no statistical difference between 9 months and 2 years, but there is a significant difference at the 5-year point.

Tetracycline stain can be removed very successfully by bleaching. The stains that are most difficult to remove are those at the cervical areas of teeth. The statement by Haywood, "The best indicator of a good

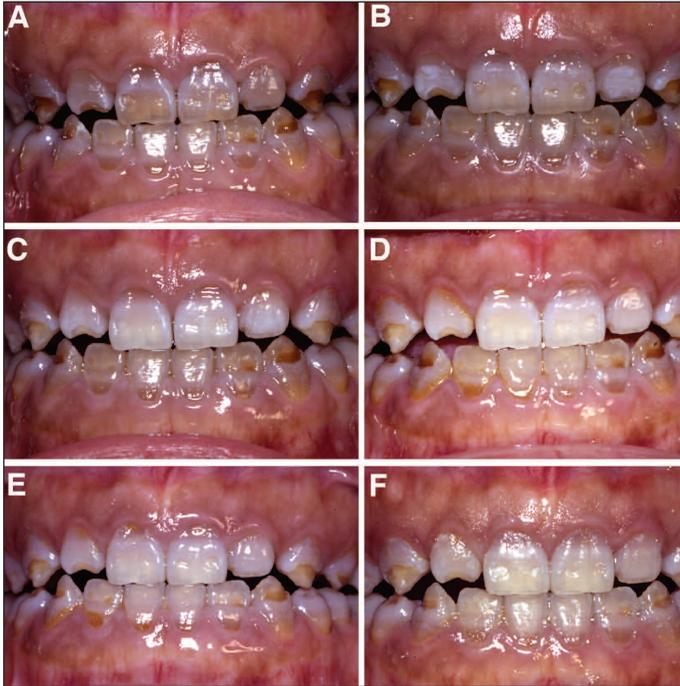


Figure 8: Subject #56 used 20% on the right side and 15% on the left side. This subject used 10% on the lower arch for 3 months and felt that the lower arch did not become as light as the maxillary teeth. Shades reported are of the middle third of the maxillary right and left centrals, respectively. A=Baseline C6/C6, B=1 month: C5/C5, C=6 months: B3/B4, D=3 months postbleaching: B3/B4, E=1.5 years postbleaching: B3/B4, F=4.5 years postbleaching: A6/A6.

prognosis is not the severity of discoloration, but the location of the discoloration,¹¹ is accurate when evaluating tetracycline-stained teeth.

CONCLUSIONS

When using 10%, 15% and 20% CP, more than 55% of the maximum lightening that occurred within 6 months happened during the first month of bleaching. Values increased the most during the bleaching of tetracycline-stained teeth. There were small changes in the green-red or blue-yellow spectrums of color throughout the study.

At 4.5 years post-bleaching, all 3 concentrations of bleaching agents had retained more than 65% of their original color change. In subjects with tetracycline-stained teeth with at least a 30% reversal of color, it is appropriate to recommend re-bleaching after 4.5 years to attain former maximum tooth lightness.

Increased tooth sensitivity occurs with higher concentrations of CP gels. If sensitivity occurs, it is appropriate to lower the concentration and inform the subjects that it will take a little longer to attain the desired tooth lightness.

Subjects with tetracycline-stained teeth need to be informed that, in most cases, the cervical areas of their teeth are the most challenging to bleach, and it may



Figure 9: Subject #17 used 20% on the right side and 15% on the left side. This subject used 20% on the lower arch for 2 months and felt that the lower arch did not become as light as the maxillary teeth. Shades reported are of the middle third of the maxillary right and left centrals, respectively. A=Baseline C7/C7, B=1 month: A4/A4, C=6 months: A3/A3.5, D=3 months postbleaching: A3.5/A3.5, E=1.5 years postbleaching: B4/B4, F=4.5 years postbleaching: A3/A3.

take longer than 6 months to attain satisfactory bleaching in that area.

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