Research Article

Assessments of a novel bleaching agent containing sodium dithionite: A laboratory study

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Abstract: Purpose: To initially evaluate the efficacy of a novel non-peroxide-based whitening strip (Dithionite White) on beverage colorants and doxycycline-stained teeth. **Methods:** In the evaluation of the beverage-stained teeth, two small areas (incisal-enamel and cervical-dentin) were exposed on bovine teeth for staining; the samples were divided into six treatment groups (n= 90) and three treatment protocols. The teeth were immersed for 14 days into six treatment groups: red wine, coffee, cola, tea, soy sauce, and an equal-part cocktail of previously listed colorants. The control group (n= 3) remained immersed in de-ionized water. The teeth were treated twice daily with Crest Whitestrips for 30 minutes and a whitening agent Dithionite White (DW) for 30 and 60 minutes on days 1, 3, 5, 7, and 14; the tetracycline-stained teeth were divided (80 teeth in the study) into eight groups (n= 10). These teeth were bleached daily. The bleaching effectiveness of the blue LED and Red infrared lights was evaluated as well as the use of mouthwash to enhance the bleaching environment. For all groups, the color change was assessed with a spectrophotometer. For the beverage-stained teeth, measurements were taken at baseline pretreatment, post-stain, 1 day, 3 days, 5 days, 7 days, and 14 days posttreatment. For the tetracycline-stained teeth, weekly measurements were obtained for 11 weeks. In each study L*, a*, b* at each period of bleaching was compared to the baseline. The color difference (ΔE) was calculated. The means ΔE were compared with multiple ANOVA tests and a MANOVA test. **Results:** In the beverage-stained and doxycycline-stained teeth, both bleaching systems showed color improvement. (*Am J Dent* 2025;38 Sp Is A:38A-43A).

Clinical significance: The results of this study support the effective use of Dithionite White (non-peroxide based) as an effective bleaching agent. Additional treatment beyond 30 minutes of DW did not significantly increase bleaching results. The adjunctive use of blue and infrared LED lights and alkalizing mouthwashes may enhance bleaching effectiveness.

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Introduction

Tooth whitening with peroxides has been proven to be safe and effective. The most used are peroxide based bleaching strips. Unfortunately, 43-80% of all beaching patients experience some temporary sensitivity after tooth bleaching with peroxides.[1] Less frequently, patients report gingival irritation. Hydrogen peroxide may produce undesirable effects on tooth structure and oral mucosa.[2] Currently manufacturers are looking for effective bleaching materials that do not contain peroxide. Riberio et al[3] found that bromelain and ficin had a whitening effect like carbamide peroxide. These enzymes also have a less erosive effect on the enamel and less cytotoxicity than hydrogen peroxide. Bizhang et al[4] reported the effective use of White Instant. This product contains the non-peroxide agents phthalimido peroxycaproic acid (PAP) and calcium lactate gluconate. Their single-use study found that White Instant produced significant initial whitening. Maquilas et al[5] reported that the sodium meta bisulfite bleaching effect was faster, higher, and with a lower concentration than carbamide peroxide. The present study compared the efficacy of bleaching agents' non-peroxide-based Dithionite White[a] (DW) to peroxide-based Crest Whitestrips[b] (Fig. 1) on external beverage and internal doxycycline-stained teeth. For external staining evaluation, five different external and one combination staining solutions were used to provide a broad-spectrum analysis of bleaching effectiveness. For the internal staining evaluation, doxycycline was chosen because of its common use and history of staining teeth. In addition to evaluating the bleaching effectiveness of DW and Crest Whitestrips on internal stains, the effect of infrared and UV LED and mouthrinse on the bleaching of internal tetracycline stains was performed. The first null hypothesis was that the non-peroxide-based DW bleaching strips were not as effective for tooth bleaching as the Crest Whitestrips. The second null hypothesis stated that there was no significant advantage to using the 60-minute DW system

Fig. 1. Dithionite White and Crest White Bleaching Strips.

Fig. 2. External staining agents.

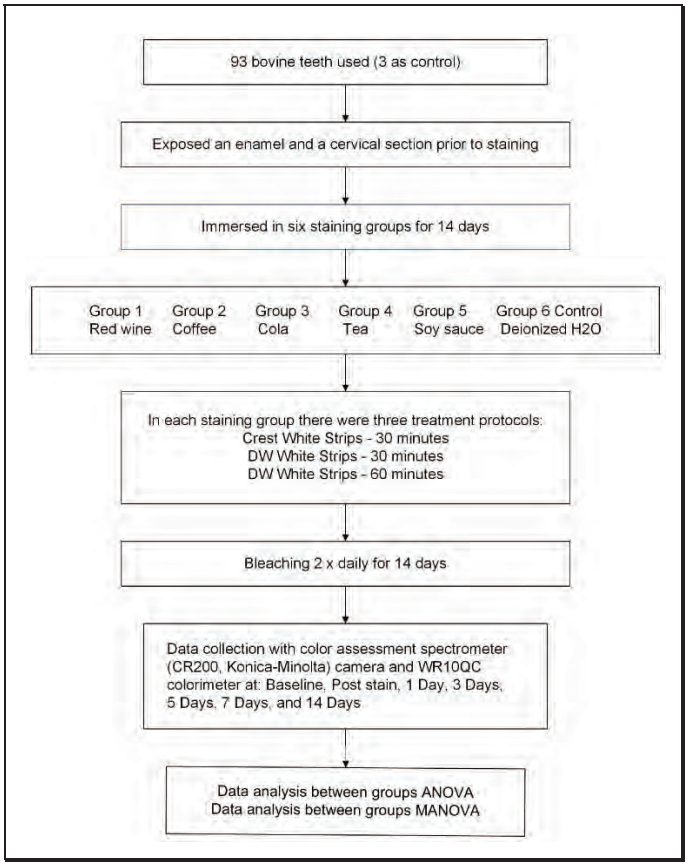

Fig. 3. Flow chart for external staining and bleaching sequence.

over the DW 30-minute system. The third null hypothesis specific to internal staining was that the use of blue or infrared LED lights alone or with the use of mouthwash would not increase the bleaching process.

Methods and Materials

In these studies, we performed external (beverage) and internal (doxycycline) staining and then evaluated bleaching effectiveness of Crest Whitestrips supreme professional whitening system and DW advanced teeth whitening strips. For external beverage staining two surface areas (enamel and cervical) were exposed on 93 bovine teeth. The enamel area was flatter than the cervical area which was more curved. These samples were divided into six treatment groups (n= 15/group) and a control group (n= 3). Each group was immersed for 14

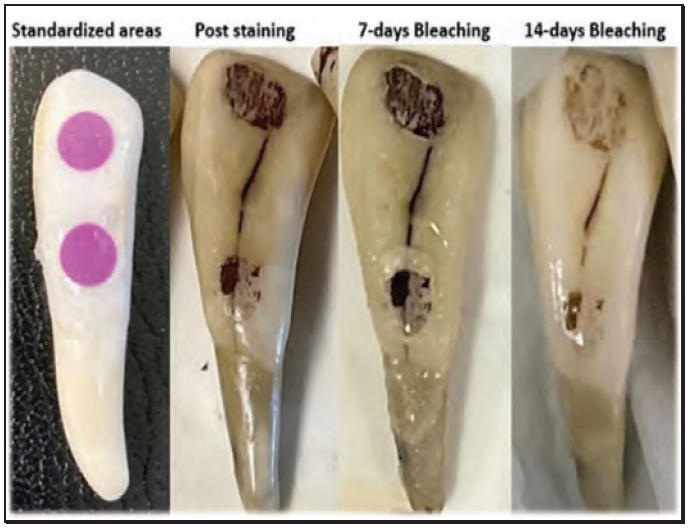

Fig. 4. Photographs of external 14-day staining and bleaching sequence (L to R).

days in one of the following 250 ml staining solutions (Fig. 2):

Group 1: Red Wine (Barefoot Rich Red Blend[c]).
Group 2: Coffee (French Roast), prepared by dissolving 4 cups of coffee grounds in boiling distilled water (Starbucks[d]).
Group 3: Cola original flavor (Coca Cola[e]).
Group 4: Extra bold black tea (Lipton[f]) prepared by leaving four tea bags in boiling water for 5 minutes.
Group 5: Soy sauce (Kikkoman[g]).
Group 6: Equal parts cocktail of all the previously listed colorants.
Control group (n= 3) = Remained in deionized water.

The teeth were assigned to one of three treatment groups: Crest Whitestrips for 30 minutes, DW for 30 minutes, and DW for 60 minutes (Fig. 3). To simulate oral bleaching conditions, the bleaching was done twice a day for 14 days following manufacturer's instructions and then the teeth were stored in distilled water between bleaching. The data collection was performed with a color assessment spectrophotometer (CR200[h]) for each study and colorimeter (WR10QC[i]) for the beverage-stained study. For the beverage-stained groups, data was obtained at baseline, post-stain, and after 1, 3, 5, 7, and 14 days of bleaching treatment (Fig. 4). In a previous analysis, the spectrophotometer proved to be more accurate than the colorimeter. Also because of the reduced variability in the enamel data as compared to the more curved dentin, the present

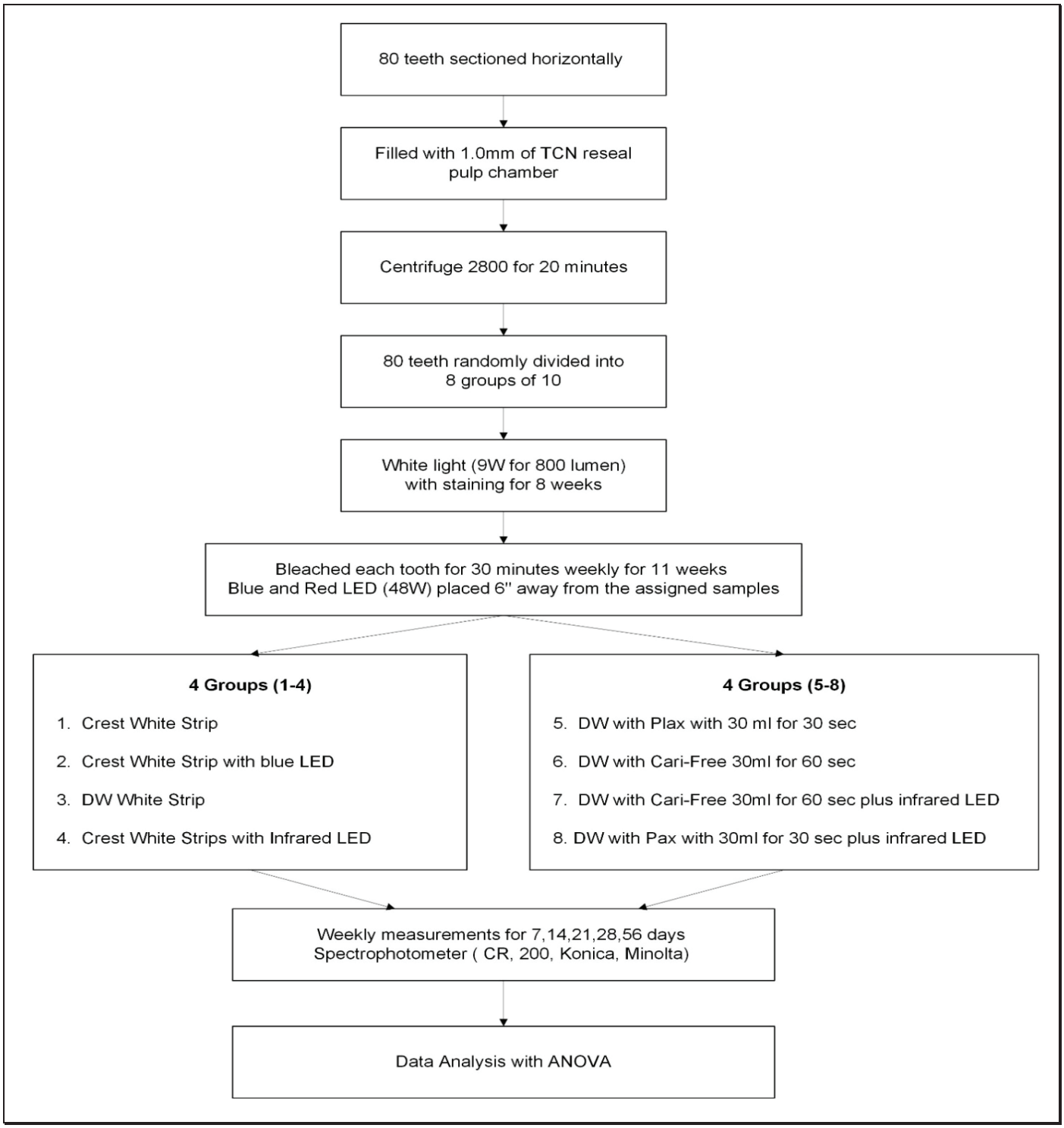

Fig. 5. Flow chart. Internal staining with doxycycline.

study utilized only the enamel data for comparison. Measurements were obtained from day 1 to day 14. The difference of L* (lightness), a* (green-red spectrum), b* (blue-yellow spectrum) at each period of bleaching is represented, under ΔL, Δa, and Δb, respectively. The color difference (ΔE) was calculated by the equation $(\Delta E) = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{½}$. For the external staining evaluation, the mean (ΔE) and mean (Δb) were analyzed with ANOVA ($P< 0.05$). The "b" value was analyzed because of the strong role that yellow plays in staining. The effect that bleaching had on each parameter (L* a*b*) was assessed with a MANOVA test.

For internal tetracycline staining, the teeth were initially soaked in saline to prevent fracture before the 80 bovine teeth were sectioned at the lingual CEJ and injected 1.0 mL of saturated doxycycline solution into the pulp chamber (Fig. 5). The teeth were then centrifuged at 2,800 RPM for 20 minutes and exposed to white light (full spectrum, 9W, 800 lumens) for 8 weeks to facilitate staining. The teeth were divided into eight groups (n= 10/group). The reason for the smaller number of teeth in the second sample was that internal staining is more

Table 1. Comparison of Delta E values across various beverages and bleaching groups (Crest, DW 30, DW 60) for different bleaching days (average values in each beverage and the bleaching group and the greatest Delta E are bolded)

Staining groups	Day 1	Day 3	Day 5	Day 7	Day 14	Mean ΔE
Red wine	2.66	3.04	3.18	4.28	14.04	5.44
Crest	3.42	4.42	3.18	2.96	11.87	5.17
DW 30	3.47	2.42	2.93	5.71	16.67	6.24
DW 60	1.08	2.28	3.41	4.18	13.58	4.91
Coffee	5.26	7.46	8.95	7.94	12.47	8.42
Crest	3.77	4.72	6.76	4.87	11.13	6.25
DW 30	5.69	10.21	11.19	8.97	13.00	9.81
DW 60	6.31	7.45	8.91	9.97	13.29	9.19
Cola	4.39	7.45	7.63	7.78	10.28	7.51
Crest	3.99	4.04	5.59	4.58	10.08	5.66
DW 30	4.17	8.46	10.44	9.22	8.90	8.24
DW 60	4.98	9.84	6.88	9.52	11.84	8.61
Tea	4.00	5.58	5.68	7.55	11.27	6.81
Crest	4.16	4.68	3.64	3.80	10.50	5.36
DW 30	3.59	6.33	8.49	8.92	10.79	7.63
DW 60	4.23	5.71	4.89	9.92	12.53	7.46
Soy	4.67	6.73	4.52	9.22	8.44	6.71
Crest	3.76	5.03	3.24	8.31	6.21	5.31
DW 30	5.09	7.43	6.37	10.74	8.01	7.53
DW 60	5.16	7.73	3.95	8.60	11.09	7.31
Cocktail	2.12	2.82	2.32	5.21	14.35	5.36
Crest	2.89	1.88	2.81	5.86	10.01	4.69
DW 30	1.85	3.59	2.57	4.50	16.97	5.89
DW 60	1.62	2.98	1.58	5.28	16.09	5.51

controlled and uniform, so there was less variability in the second study. Also, in the first study, the efficacy of the bleaching agent DW and the accuracy of the spectrophotometer (CR200) was measured with a portable colorimeter (WR 10QC). Since it was previously established, a large sample was not required for the second study. Besides measuring the effects of the addition of blue (Crest) and a red-light therapy lamp (E27,[i] 48W, infrared LED spectrum) lights, the effectiveness of a pre-treatment of Plax[j] as well as CariFree[k] mouthwash was also measured. The following groups were tested:

1. Peroxide white strip.
2. Peroxide white strip with blue LED.
3. Dithionite white strip.
4. Dithionite white strip with 24 LED infrared lamp.
5. DW with Plax 30 ml for 30 seconds.
6. DW with CariFree 30 ml for 60 seconds.
7. DW with CariFree 30 ml for 60 seconds + 24 LED infrared lamp.
8. DW with Plax 30 ml for 30 seconds + 24 LED infrared lamp.

The samples were bleached daily for 30 minutes for 11 weeks. The teeth were kept soaked in saline to simulate oral conditions. For the saline control group, no color change was noticed indicating that the saline did not affect any of the color changes. The doxycycline-stained groups were measured weekly for 11 weeks. The reason for this difference in bleaching time is that bleaching agents have less direct contact with internal stains (doxycycline) than they do with external stains (beverages). Also, the internal stains are logically more resistant to bleaching, so more time is required for bleaching. Data analysis was similar. The difference of L* (lightness), a* (green-red spectrum), and b* (blue-yellow spectrum) at each period of bleaching is represented, under ΔL, Δa, and Δb, was

Table 2. ΔE values.

External staining beverages	Mean difference	P-value ANOVA	Reject hypothesis
1. Crest/DW 30	2.1513 (significant difference)	P< 0.05 P= 0.0001	Yes (1)
2. Crest/DW 60	1.7565 (significant difference)	P< 0.05 P= 0.0015	Yes (1)
3. DW 30/DW 60	-0.3948 (Not significant)	P> 0.05 P= 0.7119	No (2)

Table 3. Delta b.

External staining beverages	Mean difference	P-value ANOVA	Reject hypothesis
1. Crest/DW 30	1.8317 (significant difference)	P< 0.05 P= 0.0001	Yes (1)
2. Crest/DW 60	1.3287 (significant difference)	P<0.05 P=0.002	Yes (1)
3. DW 30/DW 60	-0.5029 (Not significant)	P>0.05 P=0.2814	No (2)

respectively. The color difference (ΔE) was calculated by the equation:

$$(\Delta E) = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{½}.$$

For the external staining evaluation, the mean (ΔE) was analyzed with ANOVA (P< 0.05) and MANOVA for comparison of group variables. For the internal staining with evaluation, an ANOVA test for comparison of each treatment group (2-8) against the control of Crest was used and a MANOVA test for comparison of all treatment groups against the control of Crest.

Results

The bleaching of the external beverage staining was highly effective (Fig. 4). Both Crest Whitestrips and Dithionite White 30 minutes and 60 minutes lightened the teeth (Table 1). In the external beverage staining study, the mean color difference of Crest Whitestrips to DW 30 and DW 60 was compared to DW 30 to DW 60 (Table 1). DW 30 and DW 60 outperformed Crest Whitestrips for all groups with the least difference in color change with the cocktail group. The most significant improvement in color change was in the coffee and cola groups. This change was verified with an ANOVA test showing that the mean color change DW 30 and DW 60 was statistically more significant than with the Crest Whitestrips (Table 2). The mean color difference in parameter b (yellowness reduction) was also compared with an ANOVA test; the difference was significant favoring the DW 30 and DW 60 over the Crest Whitestrips. When the difference in color change and yellowness reduction of DW 30 to DW 60 was compared, the difference was minimal and not statistically significant (Table 3). With further analysis with the MANOVA test primary lightening effect of the bleach in the red wine, cola, tea, and soy groups was in Δb. The primary effect in the coffee group was in the Δa group with no statistical significance of L*a*b* in the beverage cocktail group. The bleaching of the internal tetracycline stain with Crest Whitestrips and DW 30 and DW 60 was highly effective (Fig. 6). For internal bleaching, each treatment (2-8) was individually compared to the control (Group 1 Crest

Fig. 6. Ten-week progression in bleaching Doxycycline-stained teeth.

Table. 4. ANOVA - ΔE - Comparison of bleaching effectiveness of experimental Groups 2-8 against Group 1 (Crest Control) based on Baseline L*a*b* Values and Mean ΔE.

Groups	Baseline L0 (Avg)	Baseline a0 (Avg)	Baseline b0 (Avg)	Mean ΔE All Tx	SD	P-value ΔE
Group 1	83.587	-0.831	2.577	4.51	1.49	N/A
Group 2	82.335	-0.999	3.434	6.26	1.54	7.47E-06
Group 3	82.451	-0.854	3.223	5.25	1.16	0.035
Group 4	81.439	-1.012	4.264	7.12	1.66	2.27E-09
Group 5	82.509	-0.786	3.869	6.35	1.68	8.73E-06
Group 6	82.188	-1.332	4.046	6.63	1.15	8.83E-07
Group 7	79.628	-0.982	2.391	9.21	1.65	1.31E-18
Group 8	81.857	-0.908	3.062	5.35	1.38	0.0216

Whitestrips) with an ANOVA test that showed a statistically significant increase in lightening (ΔL). When all treatments (2-8) were collectively compared to the control of Crest with MANOVA test, there was statistical significance (F= 14.73 and $P < 0.05$). More favorable results occurred with the addition of mouthwash to pre-alkalinize the bleaching environment. The most dramatic results occurred later with Group 7 which included DW with CariFree mouthwash and an infrared lamp.

The (ΔE) readings correlated well with the photographic evidence below. The results at 2, 5, and 10 weeks are shown in Fig. 6. When each treatment group (2-8) was individually compared to the Crest control using ANOVA, all treatment groups showed a statistically significant increase in ΔE. The comparison between the control and Group 7 yielded the smallest P-value (Table 4), indicating the strongest statistical significance. Group 7 consistently demonstrated the most pronounced differences in both ΔL and ΔE, suggesting it is the most effective treatment. The alkaline rinse and infrared LED light improved bleaching effectiveness.

Discussion

The effect of peroxide bleaching materials is through oxidation which involves agents that degrade the extracellular matrix to allow for oxidation or destruction of chromophores in enamel and dentin. This process may cause tooth sensitivity due to the increased dentin permeability. This increase in permeability and sensitivity is primarily related to the increased concentration and the excessive use of bleaching materials.[3] In addition to tooth sensitivity, excessive use of peroxide-based bleaching products may also produce gingival irritation. The use of a non-peroxide strip such as Dithionite White may decrease sensitivity and irritation, but more studies are necessary. The purpose of this study was to evaluate the effectiveness of the non-peroxide-based bleaching agent (Dithionite White) for both external and internal staining. This product had been previously used for industrial purposes but shows promise as a tooth-bleaching strip material. In the initial part of this study, we were able to externally stain and bleach the teeth more easily, so the results were constant. In all instances, the Dithionite White produced favorable or better results than Crest Whitestrips. In the second part of the study, the effectiveness of DW against internal doxycycline staining was evaluated.

In addition to comparing the effectiveness of sodium dithionite to peroxide bleaching agents, this study evaluated several bleaching enhancements to the internal stain. The first was the use of blue and infrared LED lights. The advantage of these lights is that they generate heat that could catalyze the oxidative process. The operating temperature is around 98°F so there are no harmful thermal effects for intraoral use. Previous studies have shown that LED and infrared lights can successfully improve bleaching effectiveness. Mena-Serano et al[6] reported that the use of the LED laser (Whitening Laser Light Plus, DMC) was effective in enhancing the whitening effect of 20% hydrogen peroxide. Vildósola et al[7] reported that whitening gel catalyzed by LED blue (1,300 mW/cm^2) and laser infrared resulted in stable and effective color changes even 1 year after therapy. Most previous studies utilized a blue LED light for bleaching enhancement, so, the introduction of infrared light is new. According to the current study, although the addition of the two lights improved the bleaching process, the improvements were not statistically significant. In the present study, the temperature of the infrared LED lights was measured during the internal bleaching protocols and ranged from 97.7°F to 99.4°F, which is like body temperature; therefore, the effect of light addition could be theorized as minimal.

The second means of bleaching enhancement was the addition of the two mouthwashes, Plax and CariFree, as co-solvents. The reason for the addition of these two mouthwashes was to provide a more alkaline environment. Plax is pH neutral and CariFree is an alkaline mouthwash. The use of peroxide often produces a more acidic environment which produces tooth erosion at pH of 5 or below.[8] Apparently, Dithionite White can bleach teeth in a more alkaline environment which will result in less tooth erosion. The use of CariFree mouthwash, an infrared light, and an increased bleaching time enhanced the bleaching process. The statistically significant difference occurred late (9-11 weeks).

Both Crest Whitestrips and DW strips are effective bleaching agents. There was some statistical significance in bleaching effectiveness with the DW system. So, the first null hypothesis was rejected. It was also noticed that increasing the bleaching time from 30 to 60 minutes did not significantly improve the results. So, the second null hypothesis was accepted. When bleaching internal staining with DW, we noticed some bleaching enhancement with the concomitant use of infrared or blue light in alkaline environments. There was a statistically significant improvement with the combination of CariFree mouthwash, infrared light, and increased bleaching time after 10 weeks of treatment. The third null hypothesis was rejected.

Further investigation is needed for this spike in bleaching effectiveness with these enhancements.

a. CAO Group, West Jordan, UT, USA.
b. Procter and Gamble, Cincinnati, OH, USA.
c. Barefoot IRL, Modesto, CA, USA.
d. Starbucks, Seattle, WA, USA.
e. Coca-Cola, Atlanta, GA, USA.
f. MANU, Glasgow, Scotland, UK.
g. Kikkoman, Tokyo, Japan.
h. Konica Minolta, Tokyo, Japan.
i. Shenzhen Panda Grow Technology, Shenzhen, China.
j. Colgate-Palmolive, New York, NY, USA.
k. CariFree, Albany, OR, USA.

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