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Comparison of Whitening Dentifrices on the Effectiveness of In-office Tooth Bleaching: A Double-blind Randomized Controlled Clinical Trial

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Clinical Relevance

The use of whitening dentifrices is not recommended during in-office tooth bleaching. However, the application of whitening dentifrices after the bleaching treatments helps to maintain the whitening results.

SUMMARY

Objectives: To investigate the effect of whitening dentifrices on the effectiveness of in-office tooth bleaching.

Methods and Materials: A double-blind randomized controlled clinical trial was performed. The participants were randomly allocated into three groups according to the different dentifrices used during this clinical trial: regular dentifrice (group C), conventional whitening dentifrice (group CW), and whitening dentifrice containing blue covarine (group CU). All participants received in-office tooth bleaching for the maxillary anterior teeth (two sessions conducted at a one-week interval). Tooth color was measured with a spectrophotometer at baseline (T1), after the first bleaching session (T2), after the second bleaching session (T3); one week after the completion of in-office bleaching (T4); and three weeks after the completion of in-office

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bleaching (T5). The data were statistically analyzed through repeated analysis of variance and the Tukey test (α=0.05).

Results: Sixty participants completed the study (n=20 per group). At T3, group CU exhibited the lowest ΔE values (p=0.008). The ΔE values increased from T4 to T5 in the CW and CU groups, whereas a decrease in ΔE values was observed for group C.

Conclusions: The use of a whitening dentifrice containing blue covarine during in-office bleaching reduced color changes. After tooth bleaching, brighter tooth colors were observed in the participants who brushed with whitening dentifrices compared to those who brushed with a regular dentifrice.

INTRODUCTION

With increasing aesthetic demands from patients, tooth whitening has become a popular treatment option for creating whiter and brighter smiles.[1-3] Currently, there are three tooth whitening approaches: at-home tooth bleaching, in-office tooth bleaching, and over-the-counter (OTC) whitening products.[4] In-office and at-home bleaching approaches are considered well-established procedures in cosmetic dentistry due to their effectiveness and safety.[5-7] Compared with at-home bleaching, in-office bleaching, which is usually performed with relatively high concentrations of hydrogen peroxide/carbamide peroxide, is more efficient and performed in weekly sessions.[8] However, in some studies, in-office bleaching has demonstrated relatively lower posttreatment color stability than at-home bleaching.[9]

In addition to in-office and at-home bleaching procedures, OTC whitening products, including whitening dentifrices and mouth rinses, have garnered increasing attention from consumers.[10] Various whitening dentifrices are currently available on the market. The components of whitening dentifrices include fluoride, pyrophosphates, triclosan, potassium nitrate, and even peroxide at low concentrations.[11] A recent systematic review concluded that whitening dentifrices demonstrate beneficial effects in reducing extrinsic tooth staining regardless of the presence of peroxide.[12] However, in terms of overall tooth color changes, previous studies have provided contrasting results regarding the effects of whitening dentifrices. In fact, different studies have reported ΔE values ranging from 0.3 to 5.1 after patients brush with the whitening dentifrices for a certain period of time.[13-17] This controversy might be explained by variations in the study protocols and the composition of the whitening dentifrices. It is only through their abrasive nature that most contemporary whitening dentifrices aid the removal of extrinsic tooth stains. Abrasiveness is influenced by particle hardness, shape, and size as well as the pH of a dentifrice.[11] Other whitening dentifrices, containing peroxide and enzymatic agents, can release free radicals to break down the chromogens of discolored teeth.[13] Moreover, whitening dentifrices containing blue covarine can change the optical properties of teeth and increase tooth whiteness.[10]

Based on the stain removal/prevention capability of a tooth whitening dentifrice, it could be postulated that the whitening dentifrice and professional bleaching treatments have synergetic effects on the final appearance of the teeth. In a laboratory study, Bortolatto and others[18] compared the efficacy of whitening dentifrices and placebo dentifrices after professional tooth bleaching treatments. The whitening dentifrices failed to provide beneficial effects on teeth previously bleached using professional bleaching treatments. Vieira-Junior and others[19] reported that the application of regular dentifrice prior to tooth bleaching has no influence on the effectiveness of bleaching treatment. Moreover, brushing with whitening dentifrices during professional bleaching procedures might increase the surface roughness of the enamel.[11,20] However, there is limited information regarding the effects of whitening dentifrices on the effectiveness of professional tooth bleaching treatments.

Therefore, this double-blind randomized controlled clinical trial aimed to determine whether whitening dentifrices would improve the effectiveness of in-office tooth bleaching procedures. The following null hypotheses were tested: 1) the use of whitening dentifrices during an in-office bleaching treatment would produce similar tooth color changes as regular dentifrice, and 2) the use of whitening dentifrices after completion of an in-office bleaching treatment would produce similar tooth color changes as regular dentifrice.

METHODS AND MATERIALS

This study was approved by the ethics committee of the local university and performed following the Consolidated Standards of Reporting Trials guidelines[21] (Figure 1), consistent with the principles of good clinical practice of the Declaration of Helsinki. This study was registered in the Clinical Trials Registry (http://www.ClinicalTrials.gov).

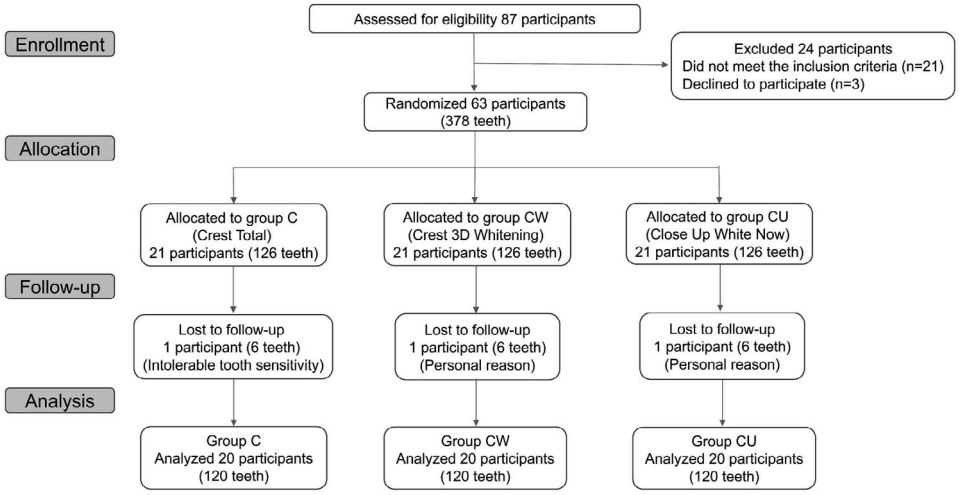

Figure 1. *Study flow diagram.*

Study Design

This study was a double-blind randomized controlled clinical trial and conducted at the Hospital of Stomatology of the local university from January 2017 to August 2017.

Inclusion and Exclusion Criteria

The participants who applied to the study were examined and selected based on the following inclusion criteria: 1) 18 to 60 years of age and in good general health; 2) six fully erupted maxillary anterior teeth, with no oral disease or dental restorations; and 3) at least one maxillary tooth demonstrating shade A3 or darker, as measured with Vita Easyshade Advance 4.0 (Vita Zahnfabrik, Bad Säckingen, Germany) (ordered by brightness). The following exclusion criteria were applied: 1) systemic diseases or oral mucosal disorders, 2) previous bleaching treatments, 3) current orthodontic treatment, 4) pregnancy, 5) known allergies to the product ingredients, 6) smoking, 7) alcohol abuse, and 8) gingival recession.[22]

At the screening visit, the selected participants gave their written informed consent to participate in the study.

Sample Size Calculation

The primary study outcome (ΔE values) was considered the variable used for sample size calculation. The sample size was calculated to obtain a ΔE difference of one unit at the end of the study between experimental group and control group.[15,23] This difference was determined by a pilot study considering the maximum standard deviations obtained. A power analysis was conducted, with 80% power at an alpha level of 0.05 for a two-tailed test. The power calculation showed that a sample size of 19 per group was necessary to detect significant differences among the groups. Assuming an anticipated dropout rate of 10%, the final sample size was defined as 21 participants per group.

Study Intervention

During this four-week clinical trial, all participants underwent two sessions of in-office bleaching treatment and were asked to use only the distributed dentifrices. A dental prophylaxis, including scaling and polishing, was performed for each participant before bleaching treatment. The polishing was finished with the aid of polishing cup and fine-grit polishing paste (Proxyt RDA 7, Ivoclar Vivadent, Schaan, Liechtenstein). Maxillary impressions of the participants were produced using alginate materials (Heraeus, Hanau, Germany), which were then poured in dental stone (Heraeus). In-office bleaching treatments were performed by a proficiency dentist who was trained and calibrated for this study using 40% hydrogen peroxide gel (Opalescence BOOST PF 40%, Ultradent, South Jordan, UT, USA). A light-cured resin barrier (OpalDam, Ultradent) was applied over the gingival tissue around the teeth to be bleached. The bleaching gels were freshly mixed and applied on the labial surfaces of the maxillary anterior teeth at a thickness of 1 mm. Two 30-minute applications were performed per session, and the bleaching gels were refreshed after each application. The bleaching sessions were performed at room temperature at a one-week interval.

Two whitening dentifrices (Crest 3D Whitening, Procter & Gamble, Blue Ash, OH, USA; Close Up White Now, Unilever, São Paulo, Brazil) and one

regular dentifrice (Crest Cavity Protection, Procter & Gamble) were used in this study. The eligible participants were randomly allocated into three groups according to the dentifrices used in this trial (n=21 per group): group C (Crest Cavity Protection, a regular dentifrice), group CW (Crest 3D Whitening, a conventional whitening dentifrice), and group CU (Close Up White Now, a whitening dentifrice containing blue covarine).

For allocation of the participants, a computer-generated list of random numbers was used. One of the investigators who was not involved in the clinical section of the study transferred the dentifrices from their original tubes to identical soft opaque tubes and labeled the tubes with numbers for each participant according to the randomization schedule. After the research assistant had obtained the participant's consent, he delivered the tubes containing dentifrices (enough for four weeks of use) to the participants together with a standard soft-bristled toothbrush (Crest, Procter & Gamble). In this manner, both the investigators and the participants were blinded to the dentifrices being delivered.

The participants were instructed to brush their teeth twice daily for two minutes each time using a Modified-Bass method. All participants were asked to avoid tobacco use and staining foods and drinks, such as curry, cola, coffee, and so on, during the experimental period. Moreover, all participants were asked to report any adverse reactions associated with bleaching, and the adverse reactions were addressed accordingly.

Evaluation

The colors were measured with CIE L*a*b* color space using a spectrophotometer (Vita Easyshade Advance 4.0). For the color measurement, a customized plastic tray with six location cones (6 mm in diameter) for each participant was fabricated. Therefore, the color measurement can be standardized by positioning the tip of the spectrophotometer with the location cones on the middle third of the labial tooth surfaces before and after each treatment. The spectrophotometer was calibrated for each subject's measurement. Tooth color was assessed at the following time points: baseline - prior to the bleaching treatment (T1), immediately after the first bleaching session (T2), immediately after the second bleaching session (T3), and one week (T4) and three weeks (T5) after the completion of the bleaching treatment. At all color measurement points, three measurements were performed for each tooth, and the average values of L*, a*, and b* were calculated for statistical analysis.

The ΔE and whiteness index (W) were further calculated using the following formulas:[24]

$$\Delta E = \sqrt{(L_i^* - L_0^*)^2 + (a_i^* - a_0^*)^2 + (b_i^* - b_0^*)^2} \quad (1)$$

and

$$W = 100 - \sqrt{[(100 - L_i^*)^2 + a_i^{*2} + b_i^{*2}]} \quad (2)$$

where L* refers to the lightness from black to white, a* refers to the color along the red and green dimension, and b* refers to the color along the yellow and blue dimension. The subscript letter "i" refers to the measurements at each testing interval, and "0" refers to the baseline measurements.

Statistical Analysis

The assumption of an approximately normal data distribution was confirmed using the Kolmogorov-Smirnov test. The L*, a*, b*, W, and ΔE values at each testing interval were analyzed using two-way repeated-measures analysis of variance to evaluate the effects of the dentifrices and testing time intervals (as a repeated measure). The data were analyzed using the SPSS statistical software package (SPSS 19.0 for Windows, SPSS, Chicago, IL, USA). All statistical analyses were performed at a significance level of 0.05.

RESULTS

Eighty-seven volunteers were screened for eligibility, 63 of whom (34 females and 29 males, mean age 26.1 years) were enrolled. Baseline and demographics data were similar across the three groups. One participant from group C declined to complete the study due to intolerable tooth sensitivity, and one participant from group CW and one from group CU were lost to follow-up for personal reasons. Sixty participants (n=20 per group) completed this clinical trial and were included in the analysis. During the treatment period, no significant adverse reactions were reported by the participants completing the study. Noticeable sensitivity was observed during and immediately after the bleaching treatment. The sensitivity usually disappeared one to two days after the bleaching treatment. Moreover, the presence of sensitivity was similar across the three groups.

Table 1: *Means and Standard Deviations of the Color Parameters (L*, a*, b*, and W) for All Groups at Different Time Points (T1 to T5)*[a]

Groups	T1	T2	T3	T4	T5
L* value					
C	74.95 (4.16) Aa	77.78 (4.09) Bb	79.56 (3.78) Dc	78.43 (4.25) Ec	78.60 (3.69) Fc
CW	74.71 (4.64) Ad	76.97 (4.75) Ce	79.61 (3.78) Df	78.27 (4.43) Eg	79.30 (4.02) Fg
CU	75.87 (4.79) Ah	77.43 (5.02) Bi	79.22 (4.16) Dj	78.42 (4.73) Ej	78.59 (4.40) Fj
a* value					
C	0.71 (1.29) Aa	0.40 (1.18) Bb	−0.78 (0.77) Cc	−1.17 (0.77) Dd	−1.06 (0.64) Fd
CW	0.62 (1.32) Ae	0.38 (1.28) Be	−0.79 (0.90) Cf	−1.07 (0.66) Dg	−1.12 (0.72) Fg
CU	0.67 (1.38) Ah	0.32 (1.18) Bl	−0.73 (0.68) Cj	−0.91 (0.83) Ej	−1.09 (0.71) Fk
b* value					
C	18.16 (4.44) Aa	17.38 (4.10) Ba	12.77 (4.02) Cb	11.17 (3.48) Dc	11.39 (3.53) Ec
CW	17.55 (4.27) Ad	17.30 (4.19) Bd	13.32 (3.43) Ce	11.03 (2.99) Df	10.94 (3.32) Ef
CU	17.79 (4.45) Ag	16.79 (3.88) Bg	13.20 (3.11) Ch	11.51 (3.13) Di	11.41 (3.41) Ei
W value					
C	68.80 (4.85) Aa	71.62 (4.96) Bb	75.62 (4.09) Cc	75.38 (3.92) Dc	75.43 (3.46) Ec
CW	68.93 (5.02) Ad	70.98 (5.36) Be	75.38 (3.90) Cf	75.36 (3.96) Df	76.30 (4.01) Ef
CU	69.78 (5.13) Ag	71.64 (5.39) Bh	75.11 (3.86) Ci	75.20 (4.08) Di	75.37 (3.78) Ei

Abbreviations: C, Crest Cavity Protection as a regular dentifrice; CW, Crest 3D White as a conventional whitening dentifrice; CU, Close Up White Now as a whitening dentifrice containing blue covarine.
[a] Values marked with the same uppercase letter were not significantly different at each time point among the three experimental groups for each color parameter (p>0.05). Values marked with the same lowercase letter were not significantly different in each group for each color parameter (p>0.05).

After bleaching, the tooth colors of the participants in all groups became whiter, with increased L* and W values and decreased a* and b* values (all $p<0.001$) (Table 1). The mean ΔE values were 8.19 for group C, 7.62 for group CW, and 6.90 for group CU. Significantly lower ΔE values were observed in group CU ($p=0.008$). After the bleaching treatment ended, an increase in the ΔE values (from T4 to T5) was observed in groups CW and CU, whereas a decrease was observed in group C (Table 2). A decrease in tooth yellowness (yellow to blue color shift, reduction in b* value) was observed in groups CW and CU, whereas an increase in b* value was recorded in group C from T4 to T5.

The ΔE values for different tooth notations were calculated by averaging the contralateral teeth (Figure 2). Significantly greater color changes were observed in the canines than in the central and lateral incisors (all $p<0.05$).

DISCUSSION

Based on the study findings, the null hypotheses that the use of whitening dentifrices during in-office bleaching treatment would produce similar tooth color changes as regular dentifrices and that the use of whitening dentifrices after the completion of in-office bleaching treatment would produce similar tooth color changes as regular dentifrices were rejected.

Over the past decade, OTC whitening products have become increasingly popular on the market. Whitening dentifrices containing abrasives, chemicals, or optical agents have demonstrated their ability to remove and prevent the formation of extrinsic stains.[10,12] However, limited evidence is available to determine whether the application of whitening dentifrices during professional bleaching treatment has effects on tooth color. The present clinical

Table 2: *Means and Standard Deviations of ΔE Values for All Groups at Different time Points (T2 to T5)*

Group	T2	T3	T4	T5
C	4.57 (2.51) Aa	8.19 (3.37) Cb	9.36 (3.05) Ec	8.85 (3.12) Gc
CW	4.19 (2.39) Ad	7.62 (2.80) Ce	8.88 (3.11) Ef	9.25 (3.73) Gf
CU	3.92 (2.20) Bg	6.90 (2.89) Dh	8.21 (3.29) Fi	8.26 (3.42) Hi

Abbreviations: C, Crest Cavity Protection as a regular dentifrice; CW, Crest 3D White as a conventional whitening dentifrice; CU, Close Up White Now as a whitening dentifrice containing blue covarine.
[a] Values marked with the same uppercase letter were not significantly different at each time point among the three groups for each color parameter (p>0.05). Values marked with the same lowercase letter were not significantly different in each group for each color parameter (p>0.05).

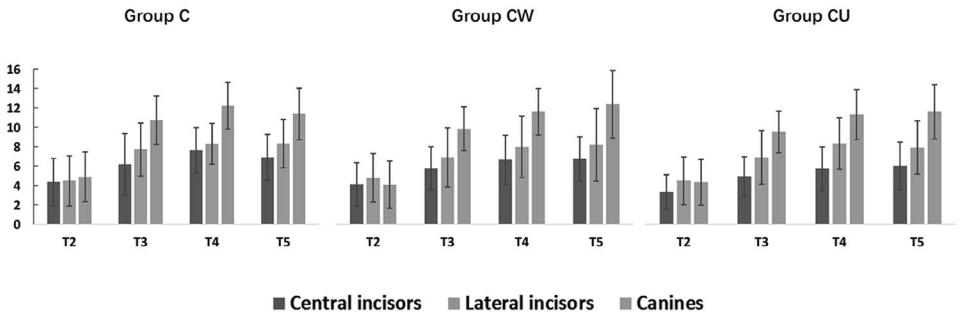

Figure 2. *ΔE values of different teeth at different time points in the three experimental groups. C, Crest Cavity Protection as a regular dentifrice; CW, Crest 3D White as a conventional whitening dentifrice; CU, Close Up White Now as a whitening dentifrice containing blue covarine.*

investigation can be considered the first clinical trial aiming to clarify the above-mentioned problem.

In the present study, groups CW and group C exhibited the same ΔE values after in-office bleaching, indicating that the tested whitening dentifrice and professional bleaching treatment had no synergistic effects on tooth color. More interestingly, group CU showed the lowest ΔE values after professional bleaching treatment (T3). The participants in group CU were asked to use a silica-based whitening dentifrice containing blue covarine. Previous studies have shown that the whitening effects demonstrated by dentifrices containing blue covarine are instantaneous, long lasting, perceivable, and measurable.[17,25] The mechanism of action is based primarily on the deposition of a thin film that is capable of altering the visual perception of the tooth color.[10] A characteristic peak of blue covarine, which contains a phthalocyanine ring structure with a tightly bound central copper ion, was observed on the enamel surface by time-of-flight secondary ion mass spectrometry.[26] This coating is deposited on the tooth surface after brushing, and it might inhibit the penetration of bleaching agents and further hinder the effectiveness of bleaching treatments. In addition, the color measurement method might be partially responsible for the current finding. The color was measured using a reflectance spectrophotometer, which was designed to analyze the dentin and deep enamel color, ignoring reflection and surface irregularities.[18,24]

In addition to the L*, a*, b*, and ΔE values, the W index was also considered in alignment with previous studies.[27,28] There were no significant differences in the W index among the three groups at the end of the study. Although the ΔE values in group C were the greatest among the three groups immediately after in-office bleaching, a decrease was observed in the ΔE values, and an increase in tooth yellowness (increase in b* value) was found three weeks after the completion of in-office bleaching. A color recession was more evident when the regular dentifrice was used than when the whitening dentifrices were used. Therefore, whitening dentifrices could be considered suitable for maintenance following professional bleaching treatments. The whitening maintenance may benefit from the silica abrasive system in the whitening dentifrices.[16,28] In the literature, silica has strong abrasive properties, whereas sodium fluoride reduces enamel abrasion.[29,30] It is possible that this color alteration results from the gradual removal of extrinsic stains through use of the abrasive agents.

Based on the current findings, patients should be advised to refrain from using whitening dentifrices while undergoing professional tooth bleaching procedures. Clinicians should advise their patients to use whitening dentifrices after their bleaching treatments to better maintain the whitening results. However, further clinical studies would be beneficial to investigate the long-term effects of whitening dentifrices on bleached teeth.

CONCLUSIONS

Within the limitations of the present study, the following conclusions can be made:

1. The use of whitening dentifrice containing blue covarine during in-office bleaching procedures was associated with less color change compared with the conventional whitening and regular dentifrices.
2. The use of whitening dentifrices after in-office bleaching procedures produced a decrease in tooth yellowness, whereas regular dentifrice was associated with an increase in tooth yellowness.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of Fujian Medical University. The approval code for this study is 20162309.

Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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