Effect of application of desensitizers before bleaching on change of tooth shade

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The aim of this in vitro study was to evaluate the effects of desensitizer pre-treatment on in-office bleaching using an artificial discoloration tooth model. The stained specimens were divided into four groups (n=10); without application (Control group), Shield Force plus (SF group), UltraEz (UE group) and Teeth Mate AP paste (TM group) applied before bleaching. Each group was bleached by an in-office bleaching agent. The CIE L*a*b* values were measured by a colorimeter before and after ten consecutive bleaching treatments and the color difference (∆E) was calculated. There was no statistical difference among ∆E values of Control, UE, and TM groups (p>0.05). There was a significant difference between SF and Control groups (p<0.001). It was concluded that application of TM and UE did not affect the change of tooth shade while SF application impeded the bleaching effect.

Keywords: Tooth bleaching, Tooth shade, Hypersensitivity, Desensitizer

INTRODUCTION

Tooth appearance is a great concern for people who wants a more pleasing smile. Esthetic dental treatments including tooth bleaching contribute to satisfy these demands. Tooth bleaching is one of the most requested dental treatments to improve or enhance a person’s beautiful smile. Vital tooth bleaching treatments are carried out either at the chair side by dentists (‘in-office’), at-home (professionally dispensed) or over-the-counter (self-administered)5. Although at-home bleaching is the most used technique for vital tooth bleaching, some patients want to see the results or treatment outcome at once and prefer more immediate results. Owing to an increased demand for shorter time, in-office bleaching has become popular option as it is performed on the same day when the patient visits the dental office. After one or a few appointments, in-office bleaching can achieve satisfactory results6. Many in-office bleaching agents contain various concentrations of hydrogen peroxide as an active ingredient. In-office bleaching treatments sometimes require light exposure to accelerate the reaction of the bleaching material. The heat generated by the light source raises the temperature of hydrogen peroxide in the bleaching material, thereby increasing the rate of decomposition of oxygen to form free radicals and enhancing the release of stain-containing molecules7. Despite the fact that bleaching systems have become increasingly popular, these may cause tooth sensitivity5. It was reported that high concentrations of in-office bleaching agents might result in tooth hypersensitivity and 67–78% patients suffered hypersensitivity when the bleaching agent was applied with heat8,9. Various methods have been proposed for prevention of hypersensitivity after tooth bleaching; such as additional ingredients of potassium nitrate, fluoride, calcium or calcium phosphate in the bleaching products7,8, post-bleaching fluoridation treatment9, use of desensitization toothpaste, application of desensitization agents, and reducing the concentration of bleaching agents and treatment time10,11.

It is therefore important to explore alternative desensitization regimens that are able to reduce or eliminate sensitivity and discomfort during and after in-office bleaching. One of the first choices is the topical application of desensitizing agents to the affected area, because it is simple and can be expected to present an immediate effect. Previous in vivo studies suggested that the use of desensitizing agents before in-office and at home bleaching had decreased the prevalence of tooth sensitivity or its intensity when compared with the use of a placebo without jeopardizing the whitening effects of bleaching agents12-14.

Recently, many types of desensitizers have been available. Although the application of those products before tooth bleaching may be able to prevent the hypersensitivity, the deterioration of bleaching effect by those applications has been unknown. Therefore, the purpose of this study was to evaluate the effect of the application of different desensitizing agents prior to in-office bleaching on change of tooth shade in vitro.

MATERIALS AND METHODS

Preparation of discolored teeth specimen
The scheme of experimental procedure is shown in Fig.
1. Extracted bovine incisors kept in a freezer until usage were employed for this study, they were thawed in running tap water, cleaned and soft tissue remnants were removed using a scalpel. Labial surfaces were ground to leave enamel of approximately 1 mm in thickness and were polished to create flat surfaces with ascending grit silicon carbide papers (Sankyorikagaku, Saitama, Japan) from #180 up to #800. Two specimens of the size of approximately 5×5 mm were obtained from the flattened surface of each tooth by a rotary diamond saw (Mini Lab-cutter MC-110, Maruto Instrument, Tokyo, Japan) under copious water. The pulpal dentin surface of each specimen was embedded in a cylindrical acrylic tube of 10 mm height and 10 mm internal diameter with dental self-curing acrylic resin (Unifast III, GC). After polymerization, the wax was removed and the dentin surface was irrigated with 5% sodium hypochlorite solution (Wako Pure Chemical, Osaka, Japan) for 1 min to remove organic tissue remnants and was etched with 40% phosphoric acid gel (K-etchant GEL, Kuraray Noritake Dental, Tokyo, Japan) for 10 s to open the dentinal tubules to increase stain uptake into the dentin. These specimens were finally polished with silicon carbide papers of #1,000, then 1,200 grit until smooth surfaces were obtained.

The tea solution was extracted by immersion of two tea bags (Lipton Yellow Label Tea bag, Unilever Japan, Tokyo, Japan) in 100 mL of boiling water for 5 min. Specimens were immersed in the tea extract and stored in an incubator for 7 days at 37°C. The solution was changed on the fourth day. After staining, the samples were rinsed with tap water and dried, then the color of enamel surface was measured with a colorimeter (NR-11, Nippon Denshoku, Tokyo, Japan) and the CIE $L^*$, $a^*$ and $b^*$ values were recorded. The surfaces were photographed with a digital camera. Forty specimens were selected, which showed between 45 and 50 of $L^*$ value in order to decrease the variation among the specimens. Because the $L^*$ value is most affected on the bleaching effect among $L^*$, $a^*$ and $b^*$ values. They were assigned into four experimental groups of 10 specimens each ($n=10$).

**Application with desensitizers**

Three desensitizers were evaluated in this study and their ingredients are listed in Table 1. All the specimens were cleaned with a polishing brush and a micro motor handpiece (NSK, Kanuma, Japan) at low speed and low pressure. Shield Force Plus (SF; Tokuyama Dental, Tokyo, Japan) is a resin-based material and Ultra EZ is a viscous gel (UE; Ultradent, South Jordan, UT, USA) which contains 3% potassium nitrate and 0.11% fluoride ion. Teeth Mate AP Paste (TM; Kuraray Noritake Dental) contains tetra-calcium phosphate (TTCP), di-calcium phosphate anhydrous and sodium fluoride.

For SF group, SF was applied to the surface of the specimen for 10 s. After drying by gentle air for 5 s, it was irradiated for 10 s using a halogen light unit (Optilux 501, Demetrom, Danbury, CT, USA) with a power intensity of 560 mW/cm². For UE group, the gel was applied and slightly agitated with a micro brush and left on the specimen for 15 min then washed with deionized water. For TM group, TM was applied for 120 s on the surface of the specimens and washed with deionized water. For the Control group, no desensitizer was applied on the surface of the specimen. The color of each specimen was measured and a photograph was taken. Obtained color values were employed as baseline data.

**Tooth bleaching**

The specimens were bleached by an in-office bleaching agent (Shofu Hi-Lite, Shofu, Kyoto, Japan) according to the manufacturer’s instruction as follows. One scoop of powder and 2 drops of liquid were mixed for 30 s to a uniform paste using a spatula provided in the kit. The paste was applied in 1–2 mm thickness onto the specimens. After leaving for approximately 6 min, the light was irradiated by a halogen light unit for 3 min. After leaving for 1 min, the paste was removed.
with a damp cotton from the specimen. Finally, the specimens were washed thoroughly under tap water, dried gently and then, the color was measured and the photograph was taken. Bleaching treatments and color measurements were repeated for 10 times for each specimen. The differences of $L^*$, $a^*$ and $b^*$ between the baseline and each step of bleaching was expressed as $\Delta L$, $\Delta a$, and $\Delta b$, respectively. The color difference ($\Delta E$) from the values obtained at the baseline and after each bleaching procedure, was calculated according to the following equation:

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$

Statistical analysis

$\Delta E$ of each bleaching step in four groups were statistically analyzed using one-way repeated measured ANOVA, Tukey post hoc test at 95% level of confidence. The analyzed factor was color difference on bleaching times.

RESULTS

The results of $L^*a^*b^*$ and the color difference values ($\Delta E$) in all groups are shown in Table 2 and Fig. 2. And typical images of each step in all groups were shown in Fig. 3. Generally, gradual but remarkable bleaching efficacy was observed after ten times applications of the bleaching agent for UE, TM and Control groups as evidenced by increasing $L^*$ value and decreasing $a^*$ and $b^*$ values. However, the bleaching effect of SF group was slight.

$L^*$, $a^*$, $b^*$ and $\Delta E$ values of SF group showed statistically differences compared to those of other groups by repeated one way ANOVA. $L^*$ values before and after application of SF group were similar to those of Control group. Through the all bleaching periods, $L^*$ values of SF group were significantly lower than those of other three groups. After second to tenth bleaching, $a^*$ values of SF group were significantly higher than those of other groups. After third to tenth bleaching, $b^*$ values of SF group were significantly higher than those of other groups.

After the first bleaching, there was no significant difference for $\Delta E$ values between SF and Control groups. The $\Delta E$ values between UE and TM groups were significantly higher than that of SF group. After second to tenth bleaching, there was a significant difference of $\Delta E$ values between SF group and other three groups, and there are no significant difference among $\Delta E$ values of UE, TM and Control groups.

DISCUSSION

In this study, an artificial discolored bovine tooth model was employed similar as previous studies\textsuperscript{15-17}. The black tea was chosen as it had been used previously in many extrinsic stain experiments\textsuperscript{15}. The stains produced by tea are easy to standardize, reproduce and control as measured by spectrophotometry. Stains produced by tea have no potential for calcification and decalcification. The stains developed by tea is almost entirely organic and it is suitable for simulating the discoloration that develops in vivo. In addition, tea is easily available, cheap and simple to use\textsuperscript{18}. The enamel of extracted bovine incisors was used in this study, because their composition is more homogeneous than human teeth, resulting in a more standardized experimental setup. Several previous studies have used the enamel of bovine teeth since its chemical composition is similar to human enamel\textsuperscript{19,20}.  

The causes of tooth discoloration are varied and complex. They can be classified according to the pass way of the diffusion of the stain as either intrinsic or extrinsic. The extrinsic discoloration arises when external chromogens lie on the external surface of the tooth or within the pellicle layer. The intrinsic discoloration occurs, when the chromogens are deposited within the bulk of the tooth, usually in the dentin by systemic or pulpaul origin\textsuperscript{21}. The assessments and measurements of tooth discoloration and bleaching can be performed by the subjective comparison methods or use of objective instrumentation. The evaluation of tooth shade by color shade guide matching is simple to use. However, it is influenced by other factors such as the observer’s experience, eye fatigue, and variation of the
Dentin is caused by thermal, physical or chemical 
mean values that can be 
showed no significantly difference (n=10).
The values with the same upper-case superscripts in each column showed no significantly difference (p>0.05).
The values with the same lower-case superscripts in each row showed show no significantly difference (p>0.05).

ambient light. In this study, color change by bleaching 
was objectively evaluated using a colorimeter. The 
colorimeter can generate accurate values that can be 
easily analyzed statistically.

Tooth sensitivity is the most common adverse 
side effect of tooth bleaching. The hydrodynamic 
theory was proposed about the mechanism of dentin 
hypersensitivity. According to this theory, sensitive 
dentin is caused by thermal, physical or chemical 
stimuli which induce fluid flow in the dentinal tubules 
and consequent nociceptor activation in the pulp-dentin 
border area. This leads to the displacement of the 
pulp-dentin fluid, which trigger pulpal sensory 
nervous terminations resulting in the characteristic 
short and sharp pain of dentin hypersensitivity. The 
etiology of sensitivity caused by tooth bleaching may 
be somewhat different. Sensitivity by tooth bleaching is 
usually transient, although if bleaching is performed
Change of $L^*$, $a^*$, $b^*$ and $\Delta E$.

(a) Change of $L^*$: The $L^*$ represents the psychometric lightness from black to white. In UE, TM and Control groups, $L^*$ values were gradually and remarkably increased. The $L^*$ value of SF group was less increased than those of other groups.

(b) Change of $a^*$: The $a^*$ axis is red on the positive side and green on the negative side. The $a^*$ value of SF group showed higher than those of other groups after second to tenth bleaching.

(c) Change of $b^*$: The $b^*$ axis is yellow on the positive side and blue on the negative side. The $b^*$ value of SF group showed higher than those of other groups after third to tenth bleaching.

(d) Color difference ($\Delta E$): As increasing bleaching times, $\Delta E$ values were gradually increased in UE, TM and Control groups. The $\Delta E$ values were not significantly different among UE, TM and Control groups. The $\Delta E$ in group is significantly higher than those in other groups.
on individuals already exhibiting sensitive dentin, the sensitivity can be severe and prolonged. From this viewpoint, tooth sensitivity caused by tooth bleaching may be also a result of fluid dynamics causing low molecular weight hydrogen peroxide diffusing through, and accumulating in the enamel and dentin. When sufficient number of bleaching molecules occupies enough intra-coronal space, pressure might be applied on pain receptors in dentinal tubules. Higher concentrations of bleaching solution increase enamel and dentin permeability and cause more sensitivity than lower concentrations\(^{24}\).

Although the bleaching agent was applied on the coronal part during the bleaching procedure, hypersensitivity usually occurred at the labial cervical area. Since the enamel is thin or sometimes dentin is exposed at the cervical area of the tooth, stimuli can easily reach the receptors in the dental pulp tissue through the dentin. A thick enamel and dentin layer may play the function as a kind of barrier, offering the pulp protection\(^{25}\). Moreover, there is a significantly positive correlation between the density of tubules and pain responses at the labial cervical area where the tubules are wider. Although the number and radius of tubules are relevant to fluid flow and therefore sensitivity, tubule radius is probably more important as fluid flow which is proportional to the fourth power of the radius. If the diameter is doubled, the tubule fluid flow increases by 16-fold\(^{26,27}\). For this reason, the coronal portion should be protected during the bleaching procedure and the cervical area should be sealed after bleaching treatment. The different morphology of teeth and the different levels of penetration of the bleaching agents into the dentin for each patient may show a various degree of hypersensitivity\(^{25}\).

Applications of a desensitizer is the first-line treatment for the dentin hypersensitivity because it is simple and fast-acting\(^{28}\). There are many types of desensitizers which have diverse mechanisms of action. Various products are available. Some contain potassium nitrate and fluoride that act to desensitize the teeth\(^{29}\) and products seal the dentinal tubules with inorganic salt crystals produced by reaction with calcium in the teeth\(^{30}\) or seal the dental tubules with resin\(^{31}\). Among them three different types of desensitizers were selected and evaluated in this study. Shofu Hi-Lite was chosen as an in-office bleaching agent in this study, which contained high concentration hydrogen peroxide with low pH. It was clinically reported that this product caused slight hypersensitivity in some cases\(^{32}\).

In this study, gradual but remarkable bleaching efficacy was observed in UE, TM and Control groups and the bleaching effect of SF group was slight. In detail, \(\Delta E\) of SF group after first bleaching was relatively high because \(b^*\) values of SF group after first bleaching was decreased as well as those of other groups. Although the reason is not clear, it was speculated that SF might react with the hydrogen peroxide molecules during the initial bleaching cycle. According to the technical report, SF is based on self-reinforcing (SR) technology characterized by an SR monomer component that penetrates into the tooth substrate, and interacts at multi-points with apatite calcium through cross-linking reactions. The ingredients of SF, shown in Table 1 have functions of coating and formation of monomer matrix. SF formed a rigid hard durable coating layer when light cured and it might have hindered the passage of the peroxide radicals. SF might have disturbed the bleaching efficacy as the coating layer was impermeable to hydrogen peroxide molecules and blocked the pathway for the penetration of peroxides. Other resinous desensitizers used for tooth bleaching were previously reported. Application
of Gluma Desensitizer Power Gel ( Heraeus Kulzer, Hanau, Germany) which contained 2-hydroxyethyl methacrylate and glutaraldehyde was effective \(^1\) with coagulation of proteins in the dentinal fluid. Another resin containing desensitizer ( MS Coat F, Sun Medical, Moriyama, Japan) hindered the bleaching effect enhancing discoloration due to capsule formation by the polymer component \(^3\). As shown in Fig. 3, shade evaluation was nearly similar after each bleaching procedure time among Control, UE and TM groups. TM contains TTCP, di-calcium phosphate anhydrous (DCPA) and 950 ppm sodium fluoride. It was reported that a mixture of TTCP and DCPA at room temperature would form hydroxyapatite in the presence of water and was effective for treating severe hypersensitivity \(^3\). Application time of TM paste for 120 s in this study might not be enough to synthesize hydroxyapatite. However, calcium phosphate salts could have precipitated on the applied surface. Although this deposited calcium phosphate salt is insoluble at an alkaline pH, this salt are soluble at less than pH 5 \(^5\). The bleaching material used in this study is acidic (pH 4.4) which may have dissolved the calcium phosphate salts. As the calcium phosphate salt might be dissolved and, the hydrogen peroxide molecules were able to penetrate and bleach the enamel. Teeth Mate Desensitizer (Kuraray Noritake Dental) also contains TTCP and DCPA and it was recommended to be used for hypersensitivity before and after bleaching by the manufacturer. The application of Teeth Mate Desensitizer did not inhibit the bleaching effect \(^3\). Since Teeth Mate Desensitizer would seal micro-cracks of enamel with similar crystalline compounds, hypersensitivity induced by the micro-crack cloud be prevented \(^6\). TM used in this study can be expected same effect because of similar composition as Teeth Mate Desensitizer. Moreover, another precursor of calcium phosphate (amorphous calcium phosphate) did not influence the tooth bleaching efficacy of tray-based bleaching gel while reducing sensitivity \(^6\). Use of desensitizing pastes containing nanocalcium phosphates prior to in-office bleaching did not influence the tooth bleaching effect \(^6\). However, it did not reduce tooth sensitivity induced by tooth bleaching in a randomized clinical trial \(^6\). With regard to color change, the results of this study indicate that the preliminary application of TM did not jeopardize the tooth bleaching effect of bleaching agent tested in this study.

UE contains 3% potassium nitrate and 0.11% fluoride providing a film-like varnish to strengthen enamel and decrease sensitivity. UE also contains potassium ions, which form ionic barriers around the pulp nerve. The increase in potassium ion concentration may cause the sustained depolarization of the nerve \(^6\). The barrier blocks neural transmission in the pulp and quietens pain or discomfort associated with hypersensitivity. Fluoride action involves modification of enamel permeability. The bleaching process is not affected as the peroxide molecules are very small and can penetrate the interstitial spaces between enamel pores. This probably explains the similar bleaching results obtained with the Control group \(^3\). Similar desensitization agents containing 5% potassium nitrate and 2% NaF did not affect the bleaching efficacy and reduced tooth hypersensitivity \(^8\). The daily use of an active 3% potassium and 0.11% fluoride desensitizing agent for 30 min prior to 10% carbamide peroxide at home bleaching gel (Opalescence, Ultradent) have been shown to prevent or decrease hypersensitivity, when compared to a placebo in an atrisk population \(^9\). The other hand, the use of UE was not found to have a statistically significant effect in reducing tooth sensitivity in patient representative of the general population \(^10\). For the above reasons and based on the limited in vitro data, TM and UE may be used before and after tooth bleaching procedure for prevention and treatment of sensitivity.

In this study, the effects of pre-application of desensitizers on tooth bleaching were varied. Clinically, suitable desensitizers should be selected and applied before bleaching procedure for prevention of hypersensitivity.

**CONCLUSION**

The application of two desensitizers (UE and TM) did not affect the change of tooth shade by office bleaching and the other one (SF) reduced the bleaching effect.

**CONFLICT OF INTEREST**

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

**REFERENCES**