INTRODUCTION

In dentistry, patients are becoming increasingly aware of the aesthetics of their dentition. Tooth discoloration is the most common reason for patient dissatisfaction with their general dental appearance. Many patients are also averse to restorations with a metallic appearance and demand natural tooth-colored materials in both posterior and anterior teeth.

Advances in our understanding of cariology have revealed the superiority of natural tooth substance in preventing caries, and the dental profession has embraced the concept of minimal intervention (MI) dentistry, where every effort is made to minimize the removal of tooth tissue during caries treatment. MI is also practiced in the esthetic treatment of discolored teeth, and a number of products falling into two main categories (bleaching and coating) are commercially available. Hydrogen peroxide, carbamide peroxide and sodium perborate are used, alone or in combination, as the active ingredients in solutions and gels for tooth bleaching. However, high concentrations of hydrogen peroxide cause significant damage to the soft tissues.

Coating technologies are similarly restricted by the fact that their effect is temporary and superficial: the tooth color itself is not improved. Moreover coating materials are discolored by exposure to chromatic beverages and test by fading testing equipment. It was postulated that endowing a surface coating material with a whitening agent will achieve the positive effects of both treatments, namely the immediate whitening effect of the coating and the more permanent effect of the bleach. The treatment time would be curtailed and the protective effects of the coat should also reduce the need for high concentrations of peroxide and thus diminish the risk of damage to soft tissues. The dentist would also gain more control over the result of the bleaching and thus increase patient satisfaction.

The aim of this study was to evaluate the properties of newly developed surface-coating materials with bleaching ability. Base resin containing sodium percarbonate (SPC) effectively bleached bovine teeth discolored by the Maillard reaction. SPC did not reduce Vickers hardness, but hardness in the hybrid material increased. The shear bonding strength of SPC-containing resin was low. No inflammation was apparent in hamster cheek pouch mucosa when exposed to SPC resin covered with a layer of base resin. H₂O₂ was released into buffer from this resin, but when placed onto tooth tissue with a protective layer of base resin, penetration of H₂O₂ into the pulp chamber was undetectable. It is concluded that SPC resin equipped with a bleaching aid can be safely used as a coating material for discolored teeth.

Keywords: Coating material, Bleaching, Sodium percarbonate

MATERIALS AND METHODS

Screening of bleaching agents

The materials used in this study are shown in Table 1. Five different bleaching agents were added to the base resin at a concentration of 1% or 5% (w/w).

As a substitute for tooth tissue, we used the shells of washed white eggs. After boiling for 30 min, eggs were discolored by the Maillard reaction. Eggs were immersed in a solution containing 0.2 mol/L glucose and 0.2% NaOH (w/v) and incubated at 60°C for 3 days. Eggshells were cut into sections measuring 1 cm×1 cm and lined with a general-purpose acrylic resin (Unifast Trad ivory, GC, Tokyo, Japan). The baseline color of specimens was assessed using the CIELab system and a dental colorimeter (ShadeEye NCC, Shofu Inc., Kyoto, Japan).

Experimental resin was applied in a 5.65 μL volume covering a 6 mm diameter on the specimen, and irradiated for 20 s using an LED curing light (Pencure, J. Morita. MFG. Corporation, Tokyo, Japan). Unpolymerized resin was removed with ethanol, and specimens were immersed individually in deionized water and incubated at 37°C for 3 days.

After the test period, the resin was removed with a metal spatula and specimen color was measured as before the experiment. Color differences were calculated between bleached samples and their respective controls using the following calculation:
Table 1  Materials used in this study

<table>
<thead>
<tr>
<th>Material</th>
<th>Lot Number</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbamide peroxide (CP)</td>
<td>MKBF0714V</td>
<td>SIGMA-ALDRICH Japan Corporation, Tokyo, Japan</td>
</tr>
<tr>
<td>Sodium perborate (SP)</td>
<td>407F1391</td>
<td>KANTO CHEMICAL, INC., Tokyo, Japan</td>
</tr>
<tr>
<td>Sodium percarbonate (SPC)</td>
<td>10142703</td>
<td>Wako Pure Chemical Industries, Ltd., Osaka, Japan</td>
</tr>
<tr>
<td>Benzoyl peroxide (BP)</td>
<td>M8E2368</td>
<td>Nacalai tesque Inc., Kyoto, Japan</td>
</tr>
<tr>
<td>Sodium metabisulfite (SM)</td>
<td>M7R7884</td>
<td>Nacalai tesque Inc., Kyoto, Japan</td>
</tr>
<tr>
<td>Base resin (composition)</td>
<td>10112</td>
<td>Kuraray medical Inc., Tokyo, Japan</td>
</tr>
<tr>
<td>(weight ratio)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bis-GMA</td>
<td>48.996</td>
<td></td>
</tr>
<tr>
<td>3G</td>
<td>48.996</td>
<td></td>
</tr>
<tr>
<td>camphorquinone</td>
<td>0.980</td>
<td></td>
</tr>
<tr>
<td>p-dimethylamino benzoic acid ethyl ester</td>
<td>0.980</td>
<td></td>
</tr>
<tr>
<td>butylhydroxytoluene</td>
<td>0.049</td>
<td></td>
</tr>
</tbody>
</table>

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

where $\Delta L^*$, $-\Delta a^*$, $-\Delta b^*$, and $\Delta E_{ab}$ are the increase in brightness, decrease in redness, decrease in yellowness, and overall color difference, respectively.

The values of $\Delta E_{ab}$ were analyzed statistically with Levene test and non-parametric Kruskal-Wallis. For the comparisons with SPC5% group and other groups, Dunnett’s test was used. All analyses were conducted using the software IBM SPSS Statistics 20 with a level of significance at 5%.

**Bleaching effect of the experimental resin**

Having identified and optimized the bleaching resin, we used bovine anterior teeth to evaluate its bleaching effect on physiological tooth tissue. Teeth were stored at 4°C in saline until use. The labial enamel surfaces were ground flat using successively finer grit waterproof abrasive papers (#600–#2000). The teeth were then discolored by the Maillard reaction. Teeth were immersed in a solution containing 0.2 mol/L glucose and 0.2% NaOH (w/v) and incubated at 60°C for 7 days.

The labial plane of each specimen was photographed and the area of the smooth plane was measured using image processing software (Adobe Photoshop CS3). This area was used to normalize the volume and thickness of resin applied. Ten specimens were divided equally into control and experimental groups. Prior to treatment, the baseline color of specimens was assessed using the CIELab system and a dental colorimeter (ShadeEye NCC). Each specimen was measured three times and averaged. To ensure that the same point was measured each time, we used an EVA Sheet (NITE White Excel EVA sheet, Discus Dental Inc., Culver City, CA, USA) with a hole excised to guide the tip of the colorimeter.

All specimens were pretreated with primer (Clearfil Megabond Primer, Kuraray Medical Inc., Okayama, Japan) for 20 s and air dried fully. In the Control group, base resin was applied at the volume calculated from the area to cover the entire smooth enamel plane with an average 0.4 mm thickness layer and irradiated (2×40 s) using a LED curing light (Pencure). In the Experimental group, resin containing 5% (w/w) SPC was spread over the enamel layer at an average thickness of 0.2 mm and irradiated (2×40 s) using a LED curing light. A second layer of base resin was then placed over the initial layer of specimens in the experimental group at an average thickness of 0.4 mm and irradiated as before. After removing any unpolymerized resin with ethanol, all specimens were immersed in deionized water and kept at 37°C.

After seven days of immersion, the resin layers were removed and tooth color (1W) was measured as before the test. Resin was then re-applied as before and incubated at 37°C in deionized water for a further seven days before measuring tooth color. This procedure was subsequently repeated once more so that readings were taken after 1, 2 and 3 weeks (1W, 2W, 3W). Data were statistically analyzed by one-way ANOVA with post-hoc Games-Howell test using the software IBM SPSS Statistics 20 with a level of significance at 5%.

**Measurement of surface hardness**

Disk-shaped specimens (10 mm diameter×2 mm thickness) were fabricated using base resin or resin containing SPC at 1, 5, or 10% (w/w). Three specimens for each condition (n=3) were irradiated for 40 s using a LED curing light (Pencure). The curing unit tip was maintained at a uniform 1 mm from the upper surface of the specimen using a transparent glass blade. Five Vickers indentations (load: 0.05 kg; dwell time: 15 s) were
performed on the surfaces of each specimen using a microhardness tester (HM-102, Akashi, Kanagawa, Japan). The specimens were then immersed in deionized water at 37°C and measured again at 1, 3, 5, 7, and 14 days. Data were statistically analyzed with Levene test and Friedman test followed by Scheffe’s paired comparison. All analyses were conducted using the software IBM SPSS Statistics 20 with a level of significance at 5%.

Adhesion to bovine enamel

The labial enamel surfaces of bovine incisor teeth were flattened using waterproof abrasive papers of increasingly fine grit (#600–#2000). The teeth were then stored at 4°C in saline until use. Teeth were fixed in a ring (Phenolic Ring Forms, Buehler, AR, USA) using a general-purpose resin (Unifast Trad pink, GC, Tokyo, Japan), dried completely with compressed air, and a piece of masking tape (0.2 mm thickness) with a 5-mm-diameter opening was placed on the center of each. The exposed region of the enamel surface was pretreated with primer (Clearfil Megabond primer) for 20 s and air-dried. Resin containing 5% SPC (w/w) was applied in a 3.93 μL volume to the pretreated surface and irradiated for 20 s using a LED curing light (Pencure). The specimens were then immersed in deionized water and stored at 37°C for 1, 3, 5 and 7 days. The specimens of the ‘0 day’ control group were not immersed and underwent shear bond testing immediately. Before shear bond testing, a brass ring (6 mm internal diameter, 2 mm height) was affixed and general-purpose resin (Unifast Trad, ivory) was filled into the ring. The shear bond test was conducted using a universal testing machine (Shimadzu compact bench-top testing machine EZTest, EZ-S, Shimadzu Corporation, Kyoto, Japan) at a crosshead speed of 1.0 mm/min.

Data were statistically analyzed by one-way ANOVA with post-hoc Scheffe’s F test using the software IBM SPSS Statistics 20 with a level of significance at 5%.

Oral mucosal irritation test

Disks of resin (10 mm in diameter and 0.6 mm in height) containing 5 or 10% (w/w) SPC were fabricated and coated with base resin (with no SPC) to 0.2 mm thickness on their upper and lower sides, and to 1 mm thickness on their lateral side. Resin was filled in a silicone mold, covered with a glass blade and cured for 40 s. The curing unit tip was maintained at a uniform 1 mm from the specimen upper surface using a transparent glass blade. Thus, resin specimens measuring 12 mm in diameter and 1 mm in height were prepared. Disks of identical size were made with only base resin to act as controls. All specimens were sterilized with ethylene oxide gas.

Fig. 1  Bleaching effect of various agents on egg-shells stained by the Maillard reaction. Stained eggshells were exposed to resin containing various types and concentrations of bleaching agents, and the various parameters of color were assessed before and after this treatment to evaluate changes. $\Delta L^*$, $-\Delta a^*$, $-\Delta b^*$, and $\Delta E^*ab$ represent the increase in brightness, decrease in redness, decrease in yellowness, and overall color difference respectively. Data are mean±SD, $n=10$. CP, carbamide peroxide; SP, sodium perborate; SPC, sodium percarbonate; BP, benzoyl peroxide; SM, sodium metabisulfite.
Table 2 Means of ∆E*ab values of various agents on egg-shells stained by the Maillard reaction, average of ranks by Kruskal-Wallis, and results of Dunnett test for the comparison with SPC5%

<table>
<thead>
<tr>
<th>Groups</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Average of ranks</th>
<th>p value of Dunnett test compared with SPC5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2.48</td>
<td>0.82</td>
<td>24.60</td>
<td>0.000</td>
</tr>
<tr>
<td>CP1%</td>
<td>4.01</td>
<td>1.22</td>
<td>47.10</td>
<td>0.000</td>
</tr>
<tr>
<td>CP5%</td>
<td>20.77</td>
<td>1.75</td>
<td>93.40</td>
<td>0.000</td>
</tr>
<tr>
<td>SP1%</td>
<td>5.59</td>
<td>1.52</td>
<td>59.95</td>
<td>0.000</td>
</tr>
<tr>
<td>SP5%</td>
<td>12.46</td>
<td>1.90</td>
<td>75.80</td>
<td>0.000</td>
</tr>
<tr>
<td>SPC1%</td>
<td>18.38</td>
<td>2.75</td>
<td>87.30</td>
<td>0.000</td>
</tr>
<tr>
<td>SPC5%</td>
<td>26.14</td>
<td>2.32</td>
<td>105.50</td>
<td>0.000</td>
</tr>
<tr>
<td>BP1%</td>
<td>1.89</td>
<td>0.93</td>
<td>16.35</td>
<td>0.000</td>
</tr>
<tr>
<td>BP5%</td>
<td>1.80</td>
<td>0.74</td>
<td>14.85</td>
<td>0.000</td>
</tr>
<tr>
<td>SM1%</td>
<td>3.41</td>
<td>0.78</td>
<td>40.50</td>
<td>0.000</td>
</tr>
<tr>
<td>SM5%</td>
<td>3.70</td>
<td>0.75</td>
<td>45.15</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 3 L*, a*, and b* values of bovine teeth before and after treatment with control or test resin

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>1W</th>
<th>2W</th>
<th>3W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>70.46(1.88)</td>
<td>71.05(2.19)</td>
<td>71.40(1.89)</td>
<td>71.11(1.94)</td>
</tr>
<tr>
<td></td>
<td>4.03(0.87)</td>
<td>4.16(0.87)</td>
<td>4.05(0.74)</td>
<td>4.30(0.81)</td>
</tr>
<tr>
<td></td>
<td>13.93(2.09)</td>
<td>13.21(2.31)</td>
<td>12.50(1.76)</td>
<td>12.27(1.83)</td>
</tr>
<tr>
<td></td>
<td>69.97(1.77)</td>
<td>72.95(2.03)</td>
<td>74.54(2.48)</td>
<td>76.01(2.60)</td>
</tr>
<tr>
<td>SPC5%</td>
<td>3.33(1.03)</td>
<td>3.03(1.03)</td>
<td>2.80(0.83)</td>
<td>2.57(0.84)</td>
</tr>
<tr>
<td></td>
<td>13.09(1.71)</td>
<td>7.56(1.49)</td>
<td>5.46(1.29)</td>
<td>4.49(1.93)</td>
</tr>
</tbody>
</table>

Results are expressed as mean (standard deviation); n=5.
Fig. 2  Bleaching of Maillard-stained bovine teeth.

(A) Bovine teeth were stained by inducing the Maillard reaction and the bleaching efficacy of a resin augmented with 5% sodium percarbonate (SPC5%) was compared to non-augmented base resin (Control). Shown are the average values±standard deviation (n=5) of \( \Delta L^* \), \( -\Delta a^* \), \( -\Delta b^* \), and \( \Delta E^*ab \) in the resin and control groups at one-week intervals. Data were statistically analyzed using one-way ANOVA with post-hoc Games-Howell test. Same letters indicate no significant differences (p<0.05).

(B) Photographs before (a) and after (b) the 3-week treatment. 1: control, 2: SPC5%.
removed with a barbed broach and the pulp chamber washed with distilled water. The roots were reinforced with composite resin. Teeth were cleaned ultrasonically in distilled water for 20 min and the buccal and lingual enamel surfaces were polished with a brush and polishing paste (Pressage, Shofu Inc., Kyoto, Japan). A 150 μL volume of reaction buffer was injected into the pulp chamber of each tooth, before a 4 mm-diameter disk of 5% SPC resin was applied to the enamel surface >1 mm from the cervical margin. This disk was then covered by a layer of base resin measuring 6 mm in diameter. The crown of the specimens were immersed in distilled water and incubated at 37°C. Reaction buffer in the pulp chamber was replaced by fresh buffer 1 h prior to each measurement. The concentration of hydrogen peroxide in the reaction buffer was measured at 1, 2, 3, 4, 5, 6, 12, 24, 48, and 72 h using a hydrogen peroxide detection kit (Fluoro H2O2™, Cell Technology Inc, CA, USA) and a multi-label plate counter (Wallac 1420 ARVO MX/Light, PerkinElmer Japan Co., Ltd., Kanagawa, Japan).

As a positive control, 5% SPC resin disks (4.0 mm in diameter and 0.2 mm in thickness) were immersed in 200 μL of reaction buffer and incubated at 37°C. The concentration of H2O2 released from the resin into the reaction buffer was measured using the same technique as for samples.

RESULTS

Screening of bleaching agents
Resins augmented with bleaching agents were applied to discolored egg-shell specimens, and differences in the $L^*$, $a^*$, $b^*$ and $\Delta E^{*ab}$ parameters pre- and post-treatment were compared (Fig. 1). The variance of $\Delta E^{*ab}$ values was not homogeneous by the result of Levene test ($p=0.000020$). The result of Kruskal-Wallis showed significant differences in the groups ($p=0.0000000$) and the highest rank was in SPC5%. Compared with $\Delta E^{*ab}$ of SPC5%, those of the other groups showed significantly smaller value by the result of Dunnett test ($p<0.01$, see Table 2).

Bleaching effect of the experimental resin
Color differences pre- and post-treatment in the control and SPC5% groups are shown in Table 3 and Fig. 2. At every time point, the values of $\Delta L^*$, $-\Delta a^*$, $-\Delta b^*$, and $\Delta E^{*ab}$ in the SPC5% group were significantly larger than in the control group ($p<0.05$) and increased with each treatment (Fig. 2A). The post-treatment difference was clearly visible (Fig. 2B).

Measurement of surface hardness
The Vickers hardness of resin immersed in water for 14 days is shown in Fig. 3. Variance was not homogeneous by the result of Levene test. By the results of Friedman test, there were significant differences in both factors, time ($p=0.0045$) and concentration of SPC ($p=0.0010$), moreover significant differences were in between no immersion and 7 days ($p=0.0412$) and in between control and 1% ($p=0.0010$) by Scheffe’s paired comparison.

Adhesion to bovine enamel
Figure 4 shows the chronological change in the shear bond strength of 5% SPC resin to an enamel surface.

Fig. 3  Vickers hardness of resins before and after immersion in water.
Resin disks (10 mm diameter, 2 mm thickness) were fabricated and immersed in water at 37 °C for varying durations. Hardness was tested periodically by making Vickers indentations with a micro-hardness tester. Data are mean±SD, n=3.

Fig. 4  Effect of SPC incorporation on shear bond strength. Resin disks (SPC5%) were placed on the labial surfaces of bovine teeth and immersed in water for varying periods, after which the disks were subjected to shear bond testing. Data are mean±SD. Data were analyzed by one-way ANOVA with post-hoc Scheffe’s F test. Same letters indicate no significant differences ($p<0.05$).
Specimens immersed in water were significantly weaker at every time point than those not immersed (p<0.05). There was no significant difference between the shear bond strength in samples immersed for different durations, suggesting that there is no time-dependence in this weakening effect.

**Oral mucosal irritation test**

Histological findings of cheek pouch mucosa after exposure to control and SPC-containing resins are shown in Fig. 5. There was no difference in the thickness of the outer epithelium between the control and SPC5% and SPC10% experimental groups indicating no inflammatory cell infiltrate, hyperemia or edema. SPC-containing resin covered with a layer of base resin thus appears to cause little or no inflammatory reaction.

**Measurement of H$_2$O$_2$ release**

The concentration of hydrogen peroxide released into the pulp chamber was invariably below the detection limit.

Figure 6 shows control experiments that demonstrate that SPC release into the buffer is initially (1–2 h) elevated before declining steadily, reaching negligible levels at 24 h.

**DISCUSSION**

We investigated the effect of augmenting tooth coating resin with bleaching agents as an alternative tooth whitening treatment and found that bleaching agents could be incorporated into these materials without inducing soft tissue inflammation or leaching peroxide into the pulp chamber.

The candidate bleaching agents are all solids at room temperature/pressure, and are used widely in other non-odontology functions such as food processing and clothes bleaching. There are two types of bleach: oxidative and reductive. We used four oxidative bleaches (carbamide peroxide (CP), sodium perborate (SP), sodium percarbonate (SPC), and benzoyl peroxide (BP)) and one
reaction9-11), a nonenzymatic chemical reaction between an amino acid and a reducing sugar. Thus, for our study we chose to use egg-shells that had been discolored in the same manner as vital teeth (i.e. by the Maillard reaction), which have the added advantage of being readily available.

Fig. 6 Resin disks containing 5% sodium percarbonate were placed into 200 μL of assay buffer and the concentration of H2O2 in this sample (i.e. released from the SPC5% resin disk) was measured at various times. Data are mean±SD, n=3.

Using these egg-shells, we noted that all of the oxidative agents except BP (Fig. 1) had bleaching efficacy. The oxidative agents react with water, subsequently decomposing and releasing hydrogen peroxide, which mediates the bleaching effect. These results suggest that applying a coating resin that contains a bleaching agent can whiten discolored teeth. We selected one of these agents, sodium percarbonate (SPC), for use as the bleaching additive in subsequent experiments.

SPC (2Na2CO3.3H2O2) is a combination of sodium carbonate and hydrogen peroxide, and can be dissolved in cold water with high solubility. In water, it decomposes to Na2CO3 and H2O2 in a weakly alkaline solution (pH10–11)12. The further decomposition of H2O2 to free radicals is catalyzed by this alkalinity. In the field of dentistry, SPC is used in dentifrice and in strips for whitening discolored vital teeth13. In the current study using discolored bovine teeth, SPC showed efficacy even when added to resin. Hasegawa et al. reported L*, a*, and b* of natural teeth in Japanese people were 73.5±5.0, 3.5±1.5, and 16.5±5.0 respectively14. In general, natural tooth color has a significant tendency to increase with the age of the subject, generally becoming darker and more yellow15,16. Human have a marked preference for ‘bluish’ (low in b*) white17. Because it influenced L* and b* (brightness and yellowness, respectively) more than a* (redness), we expect it to have maximum effect on dark and/or yellowish teeth.

Vickers hardness was measured to ascertain whether the addition of SPC affected the physical properties of the resin. The rate of polymerization changes roughly in proportion to the hardness18. Because the test resin was harder than the control, we conclude that the rate of polymerization is higher than the control. The reduced hardness values following immersion in water is probably due to water absorption and swelling, which appears to happen rapidly and fully within one day (since no further decrease in hardness was seen after this time). However, at every time point, test resin was harder than control suggesting that the incorporation of the bleaching agent has favorable effects on the physical properties of the hybrid resin.

The shear bond strength of the test resin to enamel was decreased by immersion in water. Hygroscopic expansion is believed to ease internal stresses arising from curing shrinkage19 and might be expected to increase bond strength. It is guessed that the observed decrease in bond strength is because the positive effects of this hygroscopic expansion are outweighed by the decrease in the adhesive area caused by decomposition products release from the SPC.

Supporting our belief that immersion in water changes the physical properties of the resin, our results also showed that the time course of the decrease in bond strength is similar to the chronology of the changes in Vickers hardness. The bond strength of commonly used coating materials is between 11.3–21.0 MPa19, whereas that of the test resin here is very low. However, we do not foresee this being problematic because these materials are intended for temporary (1–2 weeks) and repeated use to gain satisfaction with tooth color.

The risks of pulpal toxicity caused by dental materials are linked to the ability of their components to diffuse through enamel and dentin and invade the pulp20. It was reported that peroxide penetration into the pulp can result in different levels of tooth sensitivity and bleaching efficacy20. It was therefore necessary to measure the volume of H2O2 released from the test resin to confirm that it was not likely to cause unacceptable pulp irritation. Gökay et al. measured 0.175±0.012 μg of H2O2 in the pulp chamber following application of paint-on whitener containing 19% SPC for 30 min at 37°C20. In buffer, the concentration of H2O2 released from SPC5% resin disk (measuring 4.0 mm in diameter and 0.2 mm in thickness) was high at 1–2 h and then reduced over time to negligible levels at 24 h. However, the concentration of this H2O2 that penetrated into the pulp chamber through enamel and dentin was below detectable levels in all conditions. While this means that the product would not induce pulp irritation or pain, it
also raises questions over its whitening efficacy in the deeper layers of tooth tissue.

Fernández et al. reported \( \text{H}_2\text{O}_2 \) cytotoxicity against mouse fibroblasts at concentrations of 0.01 mM or above\(^{23}\). Long-term twice-weekly application of 3% or 30% mouse fibroblasts at concentrations of 0.01 mM or above\(^{23}\). Long-term twice-weekly application of 3% or 30% hydrogen peroxide in a hamster cheek pouch resulted in inflammatory changes (Weitzman et al., 1986)\(^{24}\) but the present study demonstrates that 5% or 10% SPC resin covered with base resin results in the complete protection of the mucosa against the inflammation-inducing effects of \( \text{H}_2\text{O}_2 \).

CONCLUSION

Within the limitations of this in vitro study, it was concluded from our results that resin augmented with SPC could be used safely on discolored teeth as a coating material (for temporary whitening) that has the additional advantageous effect of slowly releasing hydrogen peroxide for a more permanent bleaching effect. However, further studies are necessary to evaluate the clinical and other properties of this novel bleaching method.

ACKNOWLEDGMENTS

We express our thanks to Kuraray Medical Inc. for supplying the base resin. We also wish to thank the Department of Fixed Prosthetic Dentistry and the Department of Biomaterials Science, Graduate School of Medical and Dental Sciences, Kagoshima University for their collaboration in this work.

REFERENCES