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Reversal of Compromised Bonding in Bleached Enamel Using Antioxidant Gel

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Clinical Relevance

Dental bond strength is significantly reduced when bonding is performed immediately after bleaching treatments. It has also been reported that the application of an antioxidant after bleaching treatment improves the adhesive bond strength of oxidized enamel tissue. The application of an antioxidant in gel form by the patient makes the application process easier and shortens time spent in the clinic.

SUMMARY

Many studies have shown a considerable reduction in the enamel bond strength of resin composite restorations when the bonding procedure is carried out immediately after bleaching. These studies claim that a certain waiting period is needed prior to performing the restoration in order to attain the original bond strength values. This study determined the most effective time duration for the application of sodium ascorbate prepared in gel form. The labial surfaces of 70 bovine incisors were polished with 600-grit silicon carbide paper on a water-irrigated metallurgical polishing wheel. The specimens were randomly divided into seven groups: 1) bleaching (10% Rembrandt Xtra-Comfort +) immersed in artificial saliva for seven days, 2) bonded immediately after bleaching, 3) bleaching + 10% sodium ascorbate (SA) gel for 10 minutes, 4) bleaching + 10% SA gel for 60 minutes, 5) bleaching + 10% SA gel for 120 minutes, 6) bleaching + 10% SA gel for 240 minutes and 7) bleaching + 10% SA gel for 480 minutes. After preparation, a standard-shaped resin composite was applied to all specimens. The teeth were stored in distilled water at 37˚C for 24 hours and a universal testing machine determined their shear bond strength. The data were evaluated using ANOVA and Tukey tests. Antioxidant gel proved to be effective for increasing the shear bond strength of the resin composite to enamel. For maximum effectiveness, antioxidant gel should be applied to enamel for

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at least 60 minutes. As the application period of the antioxidant increased, the bond strength of the composite on enamel tissue also increased. The increase noticed in Groups 5, 6 and 7 was statistically significant ($p<0.05$). Application of the antioxidant gel by the patient shortens the time spent in the clinic.

INTRODUCTION

Bleaching treatments have become part of a dental practitioner's daily routine. These treatments are applied to vital or non-vital teeth with bleaching agents, leading to an oxidative reaction on the tissues to which they have been applied.

This corresponds to the fact that clinically visible damage due to vital bleaching has not been described in the literature, although it is reported that bleaching non-vital teeth involves the risk of developing external cervical resorption.[1-2] Despite the fact that vital bleaching is not thought to create macroscopically visible defects, some studies have exhibited micro structural changes in dental hard tissue induced by bleaching agents, especially when bleaching agents are applied in high concentrations.[3]

In addition, hydrogen and carbamide peroxide, which are commonly used bleaching agents, affect the bonding of enamel and dentin tissue when restorations are applied directly after bleaching treatment.[4-11]

Delays of one day,[4,12] three-to-seven days[5,13] and three weeks[11,14] following the bleaching procedure are recommended to enable the enamel to return to normal conditions, activating normal bond strengths and allowing the reestablishment of esthetics.

In studies carried out by Lai and others,[15-16] it was reported that the bond strength of enamel decreased after bleaching treatment. However, when the bleaching treatment was followed by treatment with sodium ascorbate, bond strength returned to its normal values. In studies by the current authors, it was demonstrated that the application of 10% sodium ascorbate to enamel and dentin after bleaching reverses bond strength.[17-20]

This study determined the most effective duration of application in which sodium ascorbate is prepared in gel form.

METHODS AND MATERIALS

Seventy two-year-old bovine incisors were extracted immediately after slaughter. Upon extraction, the teeth were cleaned of any residual tissue tags, pumiced and washed under running tap water. They were then stored in distilled water at +4˚C until needed for the study, a period not exceeding one week.

Preparation of Specimens

The roots were removed from the crowns at the cemento-enamel junction using a slow-speed diamond saw under copious water spray. Coronal pulp was removed and the canals were washed in water. The pulp chamber was filled with a light body elastomeric impression material (Xantopren VL Plus, Heraus Kulzer Gmbh & C,KG, Dormagen, Germany) to avoid penetration of the self-curing acrylic monomers into the pulp chamber.

Self-cured acrylic resin was loaded into a heavy-body silicon matrix, and the specimens were placed in the acrylic resin in such a way that their labial surfaces faced up. The samples were kept in cold water until the resin was completely cured to avoid the thermal effects generated by the resin curing process. The labial surfaces of the teeth were polished with 600-grit silicon carbide paper on a water-irrigated metallurgical polishing wheel.

Experimental Groups

The specimens were randomly divided into seven groups. Ten samples were separated as the control group (Group 1). The bleaching treatment was applied to the specimens in the control group and the specimens were kept in artificial saliva for a week prior to bonding. The remaining 60 specimens were used in six bleaching groups. Group 2 consisted of specimens bonded immediately after bleaching. The teeth in Group 3 were bleached and had 10% sodium ascorbate gel (antioxidant agent) applied for 10 minutes. The antioxidant gel application period was 60, 120, 240 and 480-minutes for Groups 4 through 7, respectively (Table 1).

Bleaching Procedure

In all seven groups, a commercial 10% CP at-home bleaching gel (Rembrandt Xtra-Comfort, Den-Mat, Santa Maria, CA, USA) was applied to the enamel surfaces of the embedded teeth for eight hours per day, according to the manufacturer's instructions. After completion of the daily bleaching procedure, the specimens were thoroughly rinsed with an air/water spray for 30 seconds and air-dried. For the remaining hours in the day, the specimens were stored in 250 ml of artificial saliva. The procedure was continued for one week.

Table 1: *Study Groups*

Groups	Bleaching Treatment	Antioxidant	Bonding
1	10% CP	None	After 7 days
2	10% CP	None	Immediately
3	10% CP	10% SA gel	After 10 minutes
4	10% CP	10% SA gel	After 60 minutes
5	10% CP	10% SA gel	After 120 minutes
6	10% CP	10% SA gel	After 240 minutes
7	10% CP	10% SA gel	After 480 minutes

Application of Antioxidant

After the bleaching procedure was completed, the antioxidant gel was prepared by using Carbopol 974P as a polymer. A certain amount of Carbopol 974P was dispersed in water by stirring. After the Carbopol 974P was dispersed, ascorbic acid was added and dissolved. Then, sodium hydroxide was added as a neutralizer to thicken the gel. The gels were poured off into small bottles and purged with nitrogen to remove oxygen. Sodium ascorbate (SA) gel was placed on the enamel surfaces of the embedded teeth for 10, 60, 120, 240 and 480 minutes. After antioxidant treatment, the enamel surface was thoroughly rinsed with distilled water for 30 seconds.

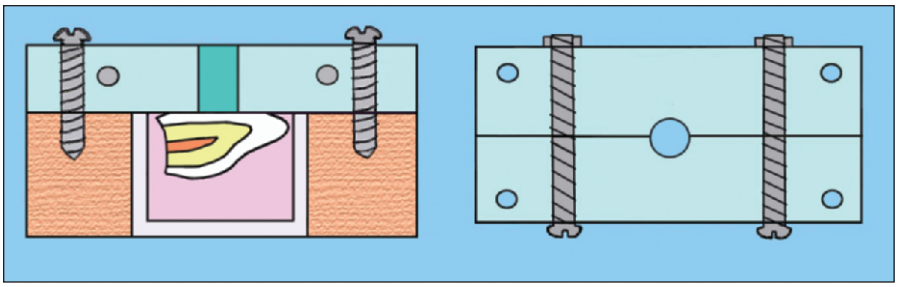

Figure 1. *Illustration of the mold used in study.*

Bonding Procedure

A piece of adhesive tape, with a hole 2 mm in diameter, was securely adapted to the center of the flattened portion of the labial enamel, limiting the bonding surface. According to the manufacturer's recommendation, an adhesive (Clearfil SE Bond, Kuraray, Osaka, Japan) was applied to the open space on the specimen. A split Teflon mold, with a circular hole 2 mm in diameter and 4 mm deep, was positioned over the hole in the adhesive tape and clamped into place with special bonding alignment apparatus (Figure 1). A resin composite (Clearfil APX, shade A3, Kuraray) was incrementally placed (Figure 2) and cured using an Optilux 401 visible light curing unit (Kerr/Demetron, Danbury, CT, USA) with an intensity output in excess of 450mW cm^2. Curing the resin in the mold formed cylindrical posts vertical to the dentin surface. Each specimen was cured for 80 seconds. After removing the bonding alignment apparatus and the split mold, the specimens were stored in distilled water at 37˚C for 24 hours. They were then subjected to 100 thermal cycles between water baths of 5˚C and 55˚C, with a dwell time of 30 seconds.

The shear bond strength was measured with a Shimadzu Universal Testing Machine (Model AG-50kNG, Shimadzu Corporation, Kyoto, Japan). A knife-edge shearing rod and a crosshead speed of 0.5 mm minute were used. The distance from the probe to the dentin surface was monitored using a spacer of two celluloid matrices. The load at failure was recorded by Labtech Notebook software (version 6.3, Labtec, Wilmington, MA, USA). The shear bond strengths of the specimens were calculated and expressed in MPa.

Fracture analysis of the bonded enamel surface was performed using a stereomicroscope (Leica MZ 7_5 Modular high performance stereomicroscope, Leica Microsystems, Wetzlar, Germany) between 10x and 12.5x magnification. Failures were classified as adhesive (>75% of failure between tooth and restorative material), cohesive (>75% of failure within the restorative material) or a mixture of the two.

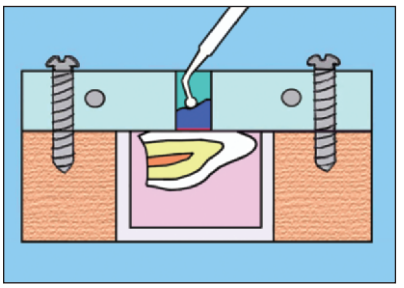

Figure 2. *Incremental placement of the resin composite.*

The shear bond strength data of the groups was analyzed by ANOVA (one-way analysis of variance) and Tukey test using SPSS 10.0 for Windows (Chicago, IL, USA). All tests were performed at a 95% confidence level.

RESULTS

The shear bond strengths in MPa (mean ± sd) for the groups are shown in Table 2. One-way ANOVA showed significant differences in bond strength among the groups ($p<0.05$). The Tukey HSD test indicated the significance of differences between the specific means (Table 2). In the groups other than Group 1, the shear bond strength exhibited a considerable increase. While the shear bond strength increase in Group 3 was not significant enough, the shear bond strength in Groups 4 through 7 was statistically significant ($p<0.05$). The application of an antioxidant gel to the bleached enamel was shown to be effective by increasing the shear bond strength of resin composite to enamel in Groups 4, 5, 6 and 7. Figure 3 summarizes the results of the shear bond strength testing.

Table 2: *Mean Values of Shear Bond Strength*

Groups	N	Bond Strength (MPa) (Mean ± sd)
1	10	24.77 ± 3.81^{abc*}
2	10	19.89 ± 2.81^{a}
3	10	21.77 ± 3.94^{ab}
4	10	24.92 ± 3.70^{bc}
5	10	28.47 ± 2.59^{cd}
6	10	29.21 ± 3.09^{cd}
7	10	33.30 ± 4.95^{d}

**Different letters indicate that there were statistically significant differences.*

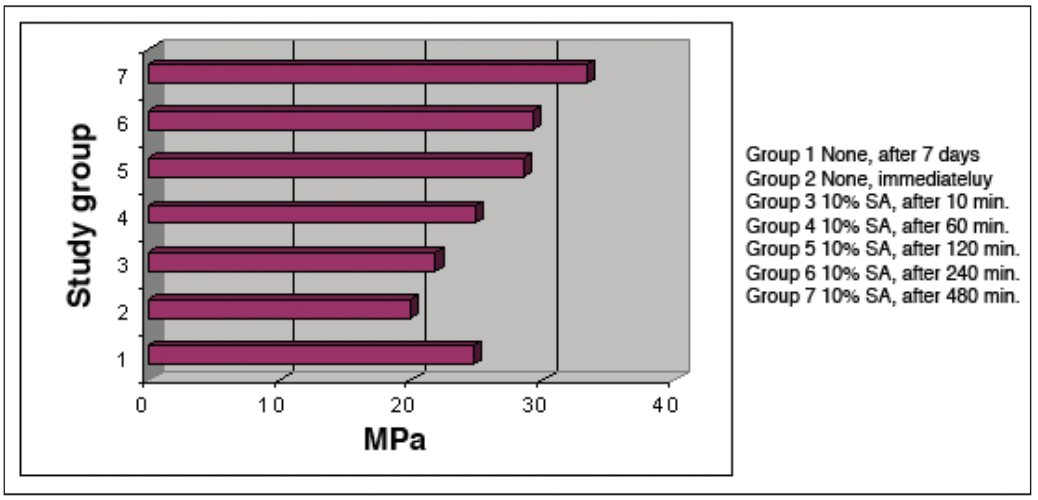

Figure 3. *Results of the shear bond strength.*

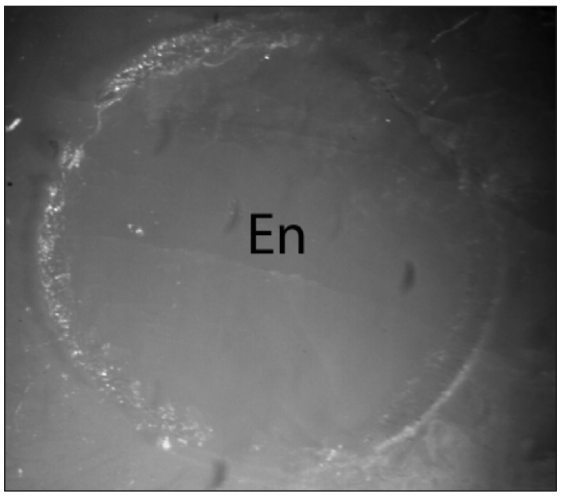

Figure 4. *Adhesive failure pattern on the debonded enamel specimen group from Group 2 (10%CP immediate bonding).*

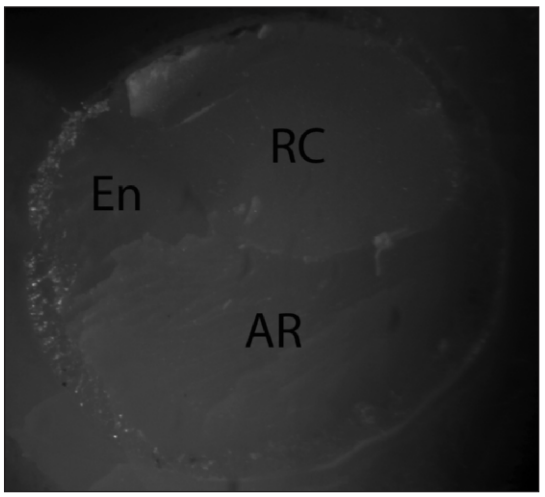

Figure 5. *Adhesive failure pattern on debonded enamel specimens from Group 3 (10%CP, 10% SA gel, 10 minutes).*

The results obtained by the multiple comparisons of the study groups are shown in Table 3. The increase noticed in Groups 5, 6 and 7 was statistically significant ($p<0.05$).

Microscopic analysis of the fractured specimens revealed that all three types of failure were observed in this study (Table 4). The number of adhesive type failures (Figure 4) was higher than the other failure types in the immediate bonding group, which was statistically significant ($p<0.05$). In all immediate bonding groups, the adhesive resin on the bleached enamel surface of the specimens showed cohesive or mixed failure patterns (Figures 5 and 6).

DISCUSSION

Bovine enamel was used as a substitute for human enamel in the bond strength testing. Although there are differences in density and porosity of human and bovine enamel,[21] the mechanism of acid etching is similar.[22] If the presence of peroxide in the prismatic spaces is the explanation for the adverse influence on adhesion, the effect on bovine enamel would not be similar to the effect on human enamel due to the inherent differences in structure and size of the interprismatic areas.[21] However, while bovine teeth do not lead to results that are identical with those obtained from human teeth, they produce results that are comparable and certainly useful in evaluating the influence of various treatments on enamel bond strengths.[9] Bovine enamel was used in the current study, both because large numbers of human enamel specimens were difficult to obtain and the current study determined the efficient time periods for the application of an antioxidant gel.

Home-bleaching that uses 10% to 22% CP is a procedure applied by the patient. Studies have shown that the bonding strength of enamel decreases after bleaching with CP in various concentrations.[7,17-20] The bleaching agents release free radicals as nascent oxygen and hydroxyl or peri-hydroxyl ions when they are applied to the dental structure. A free radical is any molecule that has one unpaired electron, providing it with high reactivity. These molecules are able to react with electron-rich regions of pigments inside the dental structure, breaking down large pigmented molecules into smaller, less pigmented ones.[23] On the other hand, this property is also deleterious to the bonding of resinous materials.

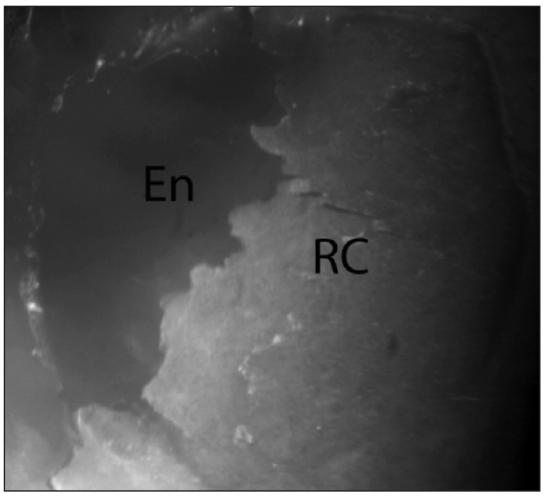

Figure 6. *Mixed failure pattern on debonded enamel specimens from Group 6 (10% CP, 10% SA gel, 240 minutes).*

Table 3: *The Comparisons of the Study Groups with Each Other*

Groups	1	2	3	4	5	6	7
1		$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p<0.05$	$p<0.05$
2	$p>0.05$		$p>0.05$	$p>0.05$	$p>0.05$	$p<0.05$	$p<0.05$
3	$p>0.05$	$p>0.05$		$p>0.05$	$p>0.05$	$p<0.05$	$p<0.05$
4	$p>0.05$	$p>0.05$	$p>0.05$		$p>0.05$	$p<0.05$	$p<0.05$
5	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$		$p<0.05$	$p<0.05$
6	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$		$p<0.05$
7	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$	$p<0.05$	

Table 4: *Types of Failure (n=10)*

Groups	Adhesive	Cohesive	Mixed
1	3	2	5
2	7	1	2
3	4	3	3
4	3	3	4
5	2	3	5
6	2	2	6
7	2	1	7

One theory proposed to explain the influence of bleaching agents on bonding suggests that peroxides and their byproducts that are present inside the dental structure are capable of interfering with the polymerization process of the adhesive material.[4-5,8,24]

According to McGuckin and others,[5] the void areas present at the bonding interface decrease in number in bonds formed at longer time intervals after the cessation of bleaching, indicating a gradual elimination of HP and its byproducts, with an increase in bond strength.

According to Titley and others,[6] the dentin and dentinal fluid can act as a peroxide and oxygen reservoir. The reservoirs of gaseous or dissolved oxygen products could persist until removed by pulpal microcirculation and diffusion from the external surface.[25] Levels of peroxide or oxygen higher than normal may be present in the bonding interface, inhibiting the polymerization reaction and reducing bond strength.[5]

Recommendations for the application of composite materials onto carbamide peroxide bleached enamel range from one day[12] to three-to-seven days[5,13] to three weeks.[14] However, in order to remove the dissolved peroxide remnants on bleached enamel, it has been demonstrated that the application of a catalase or 10% sodium ascorbate on bleached enamel and dentin immediately after the bleaching treatment makes the above mentioned waiting periods unnecessary.[15-16,26] Parallel to these studies, the current authors have demonstrated in studies that the application of 10% sodium ascorbate solution on bleached enamel and dentin could be an alternative to delayed bonding.[17-20]

In previous studies by the current authors, it was determined that 10% sodium ascorbate solution applied to the enamel surface for 10 minutes increased bond strength on the surface on which it was applied. The antioxidant was converted into gel form and used in this form in the current study. According to the results, SA in gel form significantly increased bond strength when applied for 120 minutes or more. In this study, the fact that the antioxidant becomes effective after 60 minutes stems from its conversion into gel form. When chemical substances are converted into gel form, their drug release rates are much slower than when they are in solution form.[27-28] Therefore, their efficiency periods could be much longer.

According to the results obtained in this study, the bond strength increase in Groups 5, 6 and 7 was significantly higher when compared to the other groups ($p<0.05$). These results show that an antioxidant gel becomes effective on the enamel surface after 60 minutes. In their study, Kimyai and Valizadeh[29] applied SA gel for three hours. As the application period of the antioxidant on enamel increased, the bond strength of the composite to the enamel tissue in the same study also increased. The microscopic evidence of the failure surface was in accordance with the above facts. As the application period of an antioxidant increases, the bond strength of the composite restoration increases.

For color stability, esthetic restorations must be placed at least 14 days following vital bleaching. Sodium ascorbate may be effective after seven days of

removing oxygen-free radicals but the color may regress, causing other aesthetic issues.

It was necessary to prepare the antioxidant gel on the day of the application, because the efficiency of 10% sodium ascorbate solution is swift and short-term. In the current study, since ascorbic acid was converted into gel form, its efficiency remained as long as the container cover was not opened. Thus, the utilization of an antioxidant was much easier.

In addition, the conversion of an antioxidant into gel form shortened the working hours in the clinic. Patients were able to apply this treatment by placing the antioxidant gel into the same tray used for the bleaching process, thus, the patient applied the antioxidant application process.

In this study, the application of SA gel on the enamel surface for two to eight hours was determined to statistically increase the bond strength of the composite into enamel to a significant extent. Application of the antioxidant in this way can shorten the time period spent in the clinic by the doctor and patient.

CONCLUSIONS

According to the results obtained in this study, the application of SA gel for 120 minutes after bleaching treatments increases the bond strength of the composite material to enamel tissue. The biochemical changes caused by SA gel on enamel should be examined in future studies.

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