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Effect of Delayed Bonding and Antioxidant Application on the Bond Strength to Enamel after Internal Bleaching

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Abstract

Purpose: This study evaluated the effect of delayed bonding and antioxidant application (AA, 10% sodium ascorbate) after internal bleaching (35% carbamide peroxide) on the shear bond strength of an adhesive cement to enamel.
Materials and Methods: Eighty-four human maxillary central incisors were endodontically treated. The control group remained unbleached with no AA. Experimental groups were all internally bleached. The buccal enamel was finished and polished with metallographic paper to a refinement of #600, in order to obtain a 5-mm^2 flat bonding area. An adhesive cement (Clearfil Esthetic) was placed into a plastic tube with internal diameter of 3 mm and a 3-mm height and cured on the enamel. Bonding occurred either immediately after bleaching (group Im), a 7-day delay (group 7), or a 14-day delay (group 14), and half the specimens were treated with antioxidant application (groups Im-AA, 7-AA, and 14-AA). Shear bond strength testing was performed on a universal testing machine, and data were analyzed with ANOVA and Fisher test (5%).
Results: Delaying of bonding is a useful factor for enhancing shear bond strength ($p < 0.05$), whereas AA only enhanced shear bond strength after 7 days delayed bleaching ($p < 0.05$). The highest bond strength was noted in groups 7-AA (20.51 ± 4.5 MPa), 14 (19.82 ± 4.6), 14-AA (20.27 ± 4.4), and control (20.51 ± 5.1), which were not significantly different from each other.
Conclusions: After internal bleaching, adhesive cementation to enamel is recommended only when delayed 14 days, or delayed 7 days with sodium ascorbate application.

The nonesthetic sight of discolored anterior teeth is a leading concern for a person's appearance, and modern dentistry has alternatives for this problem. Considering the needs of the patient and to achieve esthetic results, whitening may be recommended before restoring teeth with bonded restorative appliances.[1] Clinicians should evaluate the etiology of discoloration when bleaching is selected as a treatment. Intrinsic staining of nonvital teeth can effectively be removed by internal bleach.[2] Hydrogen peroxide, sodium perborate, sodium percarbonate, and carbamide peroxide can be used as bleaching agents to penetrate enamel and dentin and solubilize or decolorize the chromogens.[3]

On the other hand, clinicians should consider the effects of the selected bleaching protocol on possible future dental treatments.[4] Additional esthetic resin-bonded restorations, such as laminate or full-ceramic veneers, are often required because the results of the bleaching treatments are not always esthetically acceptable.[5] However, because of the bleaching, the bond strength of adhesive cement to dentin or enamel is reduced when the teeth are restored with adhesive-bonded veneers, and some studies have identified the presence of residual peroxide formation, which interferes with resin polymerization.[6-10]

Various protocols have been suggested to resolve this clinical problem.[11-13] The general approach is to postpone any bonding procedure by 24 hours to 4 weeks because some studies have reported that tooth bonding is insufficient within this timeframe.[8,14,15] In contrast, recent studies have proven that such a delay is unnecessary,[9,10,16] and even 10-minute applications of 10% sodium ascorbate on the bleached tooth surface is sufficient to reverse bond strength reduction.[17]

The salt of ascorbic acid, sodium ascorbate, is a potent antioxidant that can eliminate free radicals in biological systems, including oral environments, because of its nontoxicity. Therefore, sodium ascorbate is commonly used in the food industry as a safe agent.[10,18] Its efficacy for reversing compromised bonding has been proven by several studies.[8-10,16-18] The effect of vital bleaching on bonding was evaluated in all these studies; however, the effect of internal bleaching of endodontically treated teeth on bonding was evaluated in only a few of them. Therefore, the purpose of this study is to investigate the effect of delayed bonding and 10% sodium ascorbate treatment as application of antioxidant (AA) after internal bleaching with carbamide peroxide on the shear bond strength of an adhesive cement to enamel.

Table 1 Experimental design of this study

Groups	n	Condition	Delaying time	Application of sodium ascorbate
C	12	Unbleached	–	Without
Im	12	Bleached	–	Without
Im-AA	12	Bleached	–	With
7	12	Bleached	7 days	Without
7-AA	12	Bleached	7 days	With
14	12	Bleached	14 days	Without
14-AA	12	Bleached	14 days	With

Materials and methods

Eighty-four similarly sized, intact human maxillary central incisors extracted for periodontal reasons were collected and stored in normal saline. Any remnant periodontal ligaments on the teeth were removed with a curette. The pulp chamber was accessed from the lingual surface using a water-cooled spherical diamond drill (Dentsply/Maillefer, Ballaigues, Switzerland) in a high-speed handpiece. The pulp was removed with endodontic instruments, and the root canals were prepared with ProTaper rotary instruments (Dentsply/Maillefer) up to the ProTaper F3 instrument. Irrigation was performed using 5 ml of 2.5% NaOCl between each instrument during the cleaning and shaping of the root canal. The final irrigation was performed using 5 ml of 17% ethylenediaminetetraacetic acid (EDTA) for 1 minute, followed by copious irrigation with distilled water. After drying with paper points, the root canal treatments were performed with a cold lateral condensation technique using gutta-percha (Dentsply Maillefer, Petropolis, Brazil) and resin sealer (AH Plus; Dentsply DeTrey GmbH, Konstanz, Germany). Then, root canal filling material was shortened 2 to 3 mm subgingivally from the cementoenamel junction. A composite resin base was laid on the root canal filling material.

Teeth were randomly divided into seven groups of 12 teeth each and stored in distilled water (37°C ± 1°) in individual, closed bottles. The groups were separated according to the AA and the delaying time after bleaching (Table 1). In the three bleached groups, bonding procedures were performed immediately and after 7 and 14 days. In the other three bleached groups, the luting procedures were performed immediately and after 7 and 14 days following AA for 10 minutes. AA was not performed on the last unbleached specimens in order to have a control group.

Thirty-seven percent carbamide peroxide bleaching gel (Whiteness SuperEndo; Dentscare, ltda, Joinville, Brazil) was inserted into the pulpal cavities of the teeth, which were washed and dried before bleaching. After a piece of absorbent paper was placed on the gel, the access cavities were sealed with glass ionomer cement (Fuji IX GP; GC Corp., Tokyo, Japan). The teeth comprising each group were stored in distilled water (37°C ± 1°) in individual, closed containers. After 3 days, the bleaching agent was replaced with a fresh solution. This exchange was performed twice more for each bleaching group. After 9 days, the internal bleaching of all experimental specimens was completed. The control groups were not bleached but were restored with composite directly after cleaning the remnants of the endodontic treatment out of the access cavities.

After restoring the access cavities of the bleached teeth with composite resin, all teeth were completely embedded in self-cured acrylic resin to be made into separate molds ($20 \times 15 \times 10$ mm^3). Before the bonding procedure, the buccal surface of each tooth was ground and polished with metallographic paper to a refinement of #600 in the polishing machine (TegraPol 11; Struers, Ballerup, Denmark) so as to obtain a 5 mm^2 flat enamel area.

Using a syringe, a 10% sodium ascorbate solution was applied to the AA groups. Drops of the sodium ascorbate were agitated on the enamel surfaces with a microbrush for 10 minutes. Then specimens were washed and gently dried. The groups without AA were not subjected to any procedure at this time.

A dual-cure resin cement (Clearfil Esthetic Cement; Kuraray, Tokyo, Japan) was used as an adhesive for this study. According to its bonding procedure, flattened enamel surfaces were etched with K-Ecthant Gel for 10 seconds, washed, and gently dried. Then equal amounts of ED Primer II Liquids A and B were mixed and applied to the enamel surfaces of the specimens for 30 seconds. The surfaces were dried gently. Clearfil Esthetic Cement pastes A and B were mixed and placed into a plastic tube with an internal diameter and height of 3 mm, and then pressed on the flat surfaces of the specimens during the initial curing for 10 seconds. Excess adhesive cement was removed using a dental probe. Then, resin cement was polymerized from each direction with an LED curing device (light intensity: 1000 mW/cm^2; Elipar FreeLight 2 LED Curing Light; 3M ESPE, St. Paul, MN) for 40 seconds. The plastic tube was left in place for the remainder of the experiment.

After 24-hour storage at 100% humidity, the shear bond strength test was performed with a universal testing machine (Instron, Canton, MA) in which the load was applied to the enamel/cement interface using a knife-edged loading head at a 1 mm/min constant speed. The maximum load at failure was recorded in newtons (N) and converted to megapascals (MPa). The enamel surfaces of the specimens were evaluated using a scanning electron microscope (SEM) (JLeo 440, Cambridge, UK) at 50× and 1000× magnifications.

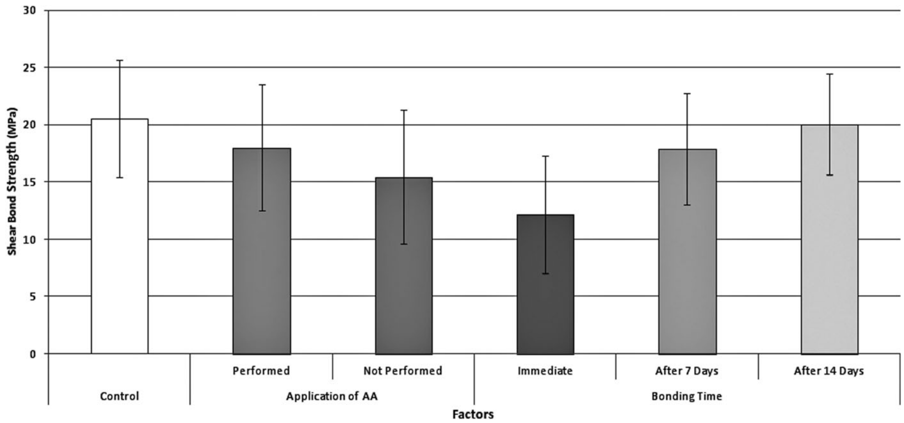

Figure 1 Mean and standard deviations of the factors of the study.

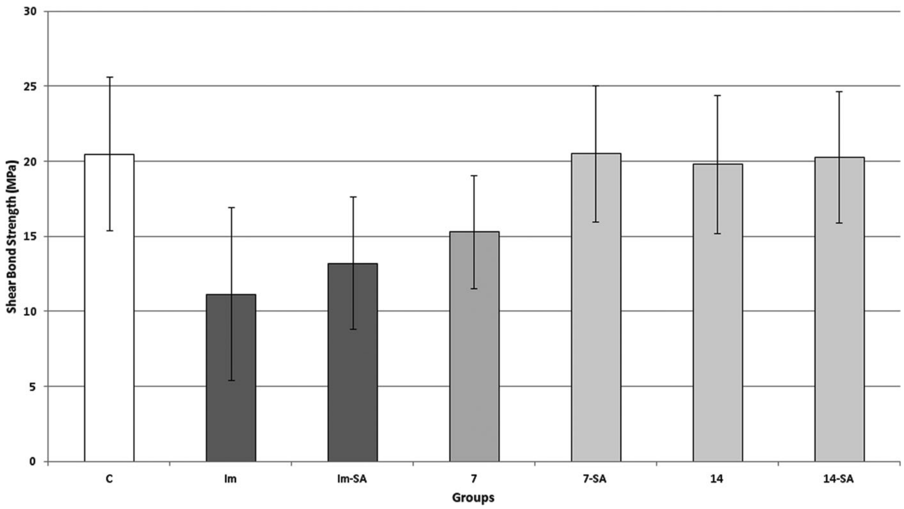

Figure 2 Mean and standard deviations of the groups of the study.

Table 2 Fracture types

	Groups						
Fracture types	C	Im	Im-AA	7	7-AA	14	14-AA
Adhesive	10	10	10	10	9	9	10
Mixed	0	0	0	0	1	1	0
Cohesive	0	0	0	0	0	0	0

Statistical analysis

First, data were evaluated with the Kolmogorov-Smirnov normality test ($\alpha = 0.05$). The mean of the normal distributed shear bond strengths of the factors analyzed was computed with two-way ANOVA. Another one-way ANOVA was used to compute the relationships among all groups. The Fisher least significant difference (LSD) test was used as a post hoc test. All analyses were performed using SPSS 20.0 (IBM Corporation Software Group; New York, NY) at a 5% level of significance.

Results

According to the results of the two-way ANOVA, different delaying times ($p < 0.0001$) and AA ($p = 0.023$) affected shear bond strength without interaction ($p = 0.209$). Bonding without AA (15.43 ± 5.9) showed lower bonding strengths than with AA and control groups ($p < 0.05$). The shear bond strengths of the control group (20.51 ± 5.1) and the groups bonded with AA (18.00 ± 5.5) did not significantly differ from each other ($p \geq 0.05$) (Fig 1). Moreover, the immediate bonding group (12.20 ± 5.1) showed lower bonding strength values than delayed bonding and the control groups ($p < 0.05$). Bonding after 7 (17.91 ± 4.9) and 14 (20.05 ± 4.4) days did not show significant differences from the control group (20.51 ± 5.1) or from each other ($p \geq 0.05$) (Fig 1).

According to the one-way ANOVA, a statistically significant difference was observed within the groups ($p < 0.0001$).

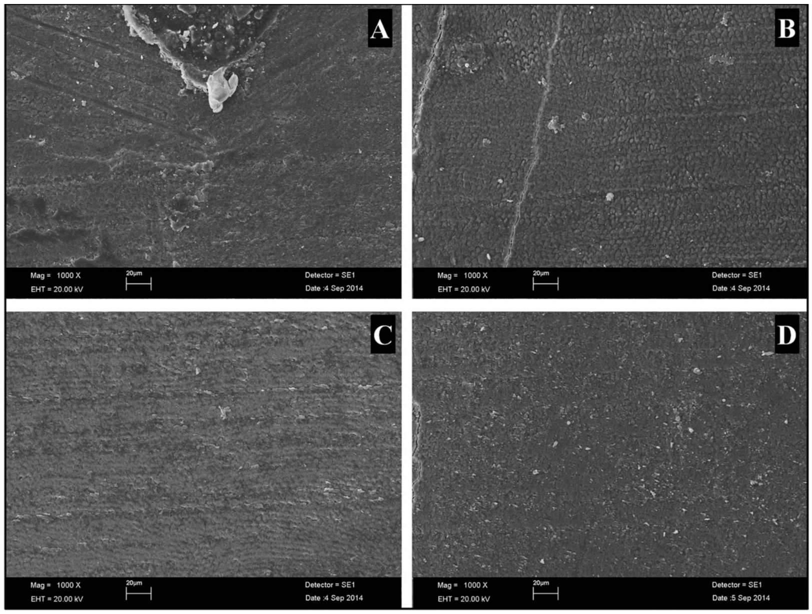

Figure 3 SEM pictures after bonding test of the control (A), Im (B), 7 (C), and 14 (D) groups.

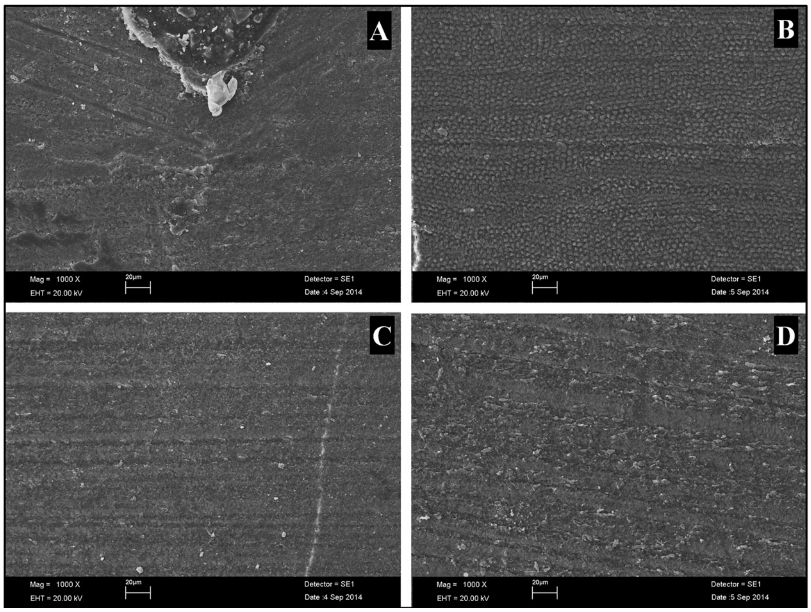

Figure 4 SEM pictures after bonding test of the control (A), Im-AA (B), 7-AA (C), and 14-AA (D) groups.

In the Fisher LSD post hoc ($\alpha = 0.05$) evaluation (Fig 2), group Im (11.17 ± 5.8) showed significantly lower shear bond strength values than all groups except group Im-AA (13.23 ± 4.4). Group Im-AA significantly differed from the other groups except for group 7 (15.31 ± 3.7), which showed significantly lower values than the rest of the groups. The 7-AA (20.51 ± 4.5), 14 (19.82 ± 4.6), 14-AA (20.27 ± 4.4), and C (20.51 ± 5.1) groups did not show significantly different shear bond strengths among each other.

According to SEM observations, there was adhesive breakage in the majority of specimens of in all groups. Almost no mixed or cohesive fracture was observed (Table 2). Therefore, there was no need to perform a statistical interpretation.

Discussion

Considering the significant dehydration that occurs in endodontically treated teeth, office bleaching often produces only short-term success. Internal bleaching is an uncomplicated and relatively low-risk intervention for improving the esthetic appearance.[2] Whichever bleaching method is chosen, the results are not always satisfactory for all patients, and alternate or further prosthodontic rehabilitations may be required.[5,17]

Many studies have evaluated the effects of vital bleaching of dentin/enamel or nonvital bleaching of dentin, on bond strength.[7-10,14,16,18,19] However, those studies did not evaluate the effect of the bleaching when it is applied to the pulp cavity and its effect on enamel bonding. Laminate veneers have been considered a conservative approach because their boundaries are limited in enamel. In such situations, bonding to nonvital bleached enamel is also important for the survival of the restoration. There appears to be no available literature that considers this issue.

According to previous studies, the bleaching process has several important local adverse effects, and perhaps the most important is the changing ratio between the organic and inorganic components of dental hard tissues.[20-22] Breakdowns of the bleaching process, which are known as free radicals,[20,23] or the delayed release of oxygen, affect resin infiltration into etched enamel and dentin or block polymerization of resins, resulting in the reduction of bond strength.[5,24,25] The immediate bond strength values in this study, which are lower than other delayed bonding times, verify this reduction.

This study has shown that these degradations are not permanent, like previous studies.[26] In some studies, different suspension times have been found useful to solve this problem.[2,14,15,27] The results obtained in the present study after postponing the bonding for 14 days are compatible with previous studies. Moreover, according to other studies, the application of antioxidants can be an option.[2,8,9,27] Ascorbic acid has been known as the most popular antioxidant, and its sodium salt reduces oxidative compounds, especially free radicals.[2,8,14,15,27] In the present study, the results of bonding tests and the SEM findings after delaying bonding for 7 days also showed improvement in groups with sodium ascorbate, with less enamel reflection due to lower resin thickness (Figs 3, 4).

Gökce et al studied external bleached enamel, and showed that 7 days postponement or the application of sodium ascorbate were effective methods for neutralizing the effects of bleaching.[28] However, in the present study, right after the last appointment of internal bleaching the application of sodium ascorbate did not solve the enamel bonding problem. We believe that this may be due to the characteristics of internal bleaching, as the internal bleaching agents affect dental hard tissues (primarily dentin, then enamel) more than the vital bleaching agent. Internal bleaching with thrice-placed bleaching agent may have caused more delayed oxygen release than vital bleaching, and 10-minute application of the sodium ascorbate was not able to reduce the oxidative compounds in the internal bleached enamel. In another study Hansen et al[29] evaluated the effectiveness of the short-term application of 35% sodium ascorbate to counteract the effects of a 7-day 35% hydrogen peroxide bleaching regimen on bond strength. The authors of this study showed that the application of 35% sodium ascorbate in a clinically relevant timeframe was not effective at reversing bleaching effects on bond strength. Hansen et al[29] emphasized that bonding procedures should be delayed following tooth bleaching. The SEM observations in the present study also showed this finding. Immediate bonding of the internal bleached group produced enamel surfaces free of resin in large areas, and resin tags are poorly defined, fragmented, or penetrated to less depth than the control group, as in previous studies.[28,30] Also, with immediate bonding, the application of sodium ascorbate did not show effective differentiation with SEM, as with bond strength (Figs 3, 4). On the other hand, the 14-day delay groups did not show any differences in bond strength and SEM observations, because the enamel condition was reversed, as in the unbleached control group specimen (Figs 3, 4).

The findings of the present study seem to have important clinical relevance for internally bleached enamel bonding; however, prospective clinical studies and further in vitro studies using mechanical fatigue tests must be conducted to support this clinical argument. Moreover, additional studies could evaluate the effects of the application of sodium ascorbate to internal bleached enamel for durations greater than 10 minutes.

Conclusions

Within the limitations of this study, the following conclusions were drawn:

1. Immediate bonding on the internal bleached enamel is not recommended, even when 10% sodium ascorbate is used as an antioxidant.
2. Postponing bonding for 7 days is not sufficient to reverse the effects of nonvital bleaching. In such situations, either the application of 10% sodium ascorbate or further postponement to 14 days might be reasonable solutions for reversing the effects of internal bleaching.

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