



## Effect of Two-minute Application of 35% Sodium Ascorbate on Composite Bond Strength following Bleaching

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### ABSTRACT

**Aim:** The aim of this study is to assess the effect of 35% sodium ascorbate on microtensile bond strength of dentin immediately after bleaching with 35% hydrogen peroxide.

**Materials and methods:** A total of 25 sound human 3<sup>rd</sup> molars were collected. Teeth were randomly divided into five groups for different treatments: Group I [bleaching + immediate bonding (i.e., restoration)], group II (bleaching + delayed bonding), group III (bleaching + sodium ascorbate + immediate bonding), group IV (bleaching + sodium ascorbate + delayed bonding), and group V (bonding only). After bleaching, but before bonding, groups II and IV were stored for 1 week in deionized water at 37°C. All samples were bonded using OptiBonded FL (Kerr) and Filtek Supreme (3M/ESPE). Teeth were sectioned into 1 × 1 mm 2 bars, and microtensile bond strength was tested with a universal testing machine (Instron 8841) at a cross-head speed of 0.5 mm/minute.

**Results:** Microtensile bond strength differed significantly across the five groups, with a significant reduction in microtensile bond

strength observed for samples in group I relative to samples in any of the other treatment groups ( $p < 0.05$ ).

**Conclusion:** The application of a high concentration of sodium ascorbate for a shorter time reversed the negative effect of 35% hydrogen peroxide bleaching on composite bonding strength to dentin.

**Clinical significance:** The negative effects of bleaching on composite bonding can be neutralized by the application of the reversing agent sodium ascorbate thus, increasing the efficiency of clinic chair time. This is clinically relevant for those patients requiring restorative treatment immediately after in-office bleaching.

**Keywords:** Antioxidants, Ascorbic acid, Bleaching agents, Composite resin, Dentin, Esthetic, Hydrogen peroxide, Laboratory research.

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**Conflict of interest:** None

### INTRODUCTION

The negative effect of bleaching on composite resin bonding is temporary and depends on the length of time between the two events. To avoid the weakening effects of bleaching, it is important to delay performing any type of composite resin bonding following treatment.<sup>1</sup> Many studies have attempted to find a solution to reverse this mechanism to avoid this inconvenient delay. Sodium ascorbate antioxidant solution has been investigated for its potential use to reverse the temporary weakening

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effects of bleaching agents on resin bonding.<sup>2-4</sup> The entrapment of residual bleach by-products in the collagen matrix and dentinal tubules is a suggested reason behind the reduction in bond strength upon bleaching.<sup>5</sup> In studies of failed bonded specimens, residual oxygen was found to be trapped within the tooth structure preventing resin tags from fully penetrating and interlocking the tubules.<sup>1,6</sup> Other studies have also implied that the residual peroxide from the bleaching reaction inhibits composite polymerization.<sup>7,8</sup> Due to the widespread use of bleaching, further investigation into how it affects composite resin bonding is necessary for optimizing patients' esthetic outcome.

Sodium ascorbate is a bioavailable form of vitamin C, has neutral pH, and is a biocompatible agent, i.e., widely utilized in the food industry. The effects of sodium ascorbate antioxidant treatment are dependent on: (1) The concentration of the bleaching agent, (2) the concentration of the antioxidant, (3) the application time of antioxidant treatment, and (4) the contact time of the antioxidant.<sup>9</sup> This is evident in a study by Freire et al,<sup>10</sup> which revealed that oxygen released by hydrogen peroxide could only be neutralized if a proportional amount of sodium ascorbate was used, although this correlation has not been confirmed using a microtensile bond strength test. Further studies have demonstrated that concentrations of 10 to 20% sodium ascorbate solution result in significant improvements in bond strength values when applied after bleaching with carbamide peroxide, which is commonly used for home bleaching.<sup>4,11-15</sup> In contrast, improvements in bond strength upon treatment with sodium ascorbate were less significant when hydrogen peroxide gel was used as the whitening agent.<sup>16-18</sup> Another factor that has been studied on human teeth is the application time of the sodium ascorbate solution. This varies in the literature between 10 minutes and 3 hours,<sup>3,17-20</sup> which is inefficient from a clinical perspective. There are some clinical scenarios where an immediate restoration is needed after bleaching with hydrogen peroxide or where waiting for the tooth color to stabilize is not necessary. Thus, the effects of a brief application of high concentration sodium ascorbate on composite resin bonding to dentin following bleaching with hydrogen peroxide have not been completely elucidated.

The purpose of this randomized, controlled, *in vitro* study was to evaluate the effects of a 2-minute application of 35% sodium ascorbate on the microtensile bond strength of the composite resin–dentin interface immediately or 1 week following hydrogen peroxide bleaching. The null hypothesis is that application of 35% sodium ascorbate for 2 minutes at any point after hydrogen peroxide bleaching will not significantly improve the microtensile bond strength of the composite resin–dentin interface when compared with hydrogen peroxide bleaching alone.

## MATERIALS AND METHODS

This study was initiated after the approval of the Institutional Review Board at Nova Southeastern University. A total of 25 extracted human molars were collected from a deidentified bank of teeth. Sample size was based on our pilot study and G power calculation. Selection criteria included human third molars with an intact occlusal surface and no enamel defects. Teeth were rinsed and cleansed of any residual debris and stored in distilled water at +4°C. One examiner was in charge of sample preparation and testing.

### Sample Preparation

The occlusal table was removed using an IsoMet low-speed saw (Buehler, Illinois, USA) under running water. Finishing and polishing were completed using abrasive (SiC) papers of 400 and 600 grits, successively, for 10 seconds each (Metaserve, 2000; Variable speed grinder-polisher, Buehler, Illinois, USA).

### Bleaching Treatment

The bleaching treatment involved the application of 35% hydrogen peroxide bleaching gel (Pola Office, SDI, Australia) according to the manufacturer's instructions for three cycles. Teeth were randomly divided into five groups with each group comprising five teeth. Group I received bleaching followed immediately by bonding of composite resin (positive control). Group II received bleaching followed by bonding of composite resin 1 week after bleaching, according to the common practice (positive control). Group III received bleaching followed by immediate treatment of 35% sodium ascorbate and immediate bonding of composite resin (treatment group). Group IV received bleaching followed by immediate treatment of 35% sodium ascorbate. Bonding of composite resin was performed after 1 week (treatment group). Group V received bonding of composite resin without bleaching or treatment with sodium ascorbate (negative control).

### Sodium Ascorbate Preparation and Application

Sodium ascorbate solution was prepared and mixed fresh for each treatment group. To prepare a 35% sodium ascorbate solution, 3.5 gm of sodium ascorbate (98% purity Sigma-Aldrich Co., St. Louis, MO, USA) was diluted in 10 mL of distilled water, pH 7.0, and agitated using the SP Vortex Mixer (Baxter Scientific Products, Brighton, Michigan, USA). Immediately after the bleaching agent was rinsed, two applications of 35% sodium ascorbate solution were applied for 1 minute each using a microbrush (groups III and IV), followed by rinsing

for 60 seconds according to the method described by Freire et al.<sup>9</sup>

Specimens in which bonding was delayed for 1 week after bleaching (groups II and IV) were stored in deionized water at a temperature of 37°C for 1 week in an Isotemp incubator (Fisher Scientific, Waltham, Massachusetts, USA). After 1 week in storage, samples were treated with 35% sodium ascorbate solution (group IV) as described earlier, followed by composite resin bonding, or were immediately used for composite resin bonding (group II).

### Bonding of Composite Resin

After prophylaxis with pumice, the exposed dentinal surface was etched using 37.5% phosphoric acid (Best etch, Vista, Racine, Wisconsin, USA) for 15 seconds, then rinsed, and dried. OptiBond FL adhesive system was used according to the manufacturer's instructions (Kerr, Orange, California, USA), then light cured for 20 seconds using a halogen LC unit Optilux 501 (Kerr, Orange, California, USA) with an intensity output of 800 mW/cm<sup>2</sup>. Composite (Filtek Supreme, 3M ESPE, St. Paul, MN, USA) was condensed with the aid of metal band as a matrix in increments, then light cured. Samples were stored in deionized water in an incubator (Fisher Scientific, Waltham, Massachusetts, USA) at a temperature of 37°C for 24 hours to allow the polymerization reaction of the composite to be completed. A 1-mm mark on the periphery of each sample was made with a marker so enamel could be excluded after sectioning.

### Sample Sectioning and Microtensile Bond Strength Test

Preparation of samples for the microtensile bond strength test was performed as described by Pashley et al.<sup>21</sup> Teeth were sectioned using a diamond blade with a low-speed saw (Isomet, Buehler, Illinois, USA). Each bonded tooth was sectioned vertically into several slabs of 1-mm thickness (4–5 slabs per tooth). Samples were rotated 90° and again sectioned lengthwise into multiple beam-shaped bars, each with a cross-sectional surface area of approximately 1 mm<sup>2</sup>. For each group of five samples, bars from individual samples were pooled and 50 bars per group were randomly selected for the microtensile bond strength test. Bars were positioned on a universal loading machine (Instron model 8841, Instron, Canton, Massachusetts, USA) and each end of the specimen was aligned on marked lines and glued with cyanoacrylate glue. The tensile load was applied at a cross-head speed of 0.5 mm/minute until the specimen was fractured. The load at failure was recorded in Newton (N) and later converted to failure strength (MPa). Each specimen was examined under a stereomicroscope at ×25 (Bausch

and Lomb, Bridgewater, New Jersey, USA). Adhesive fractured bars were included whereas cohesive fractured bars were excluded. Only samples that generated a load at failure measurement were used to calculate the bond strength.

### Statistical Analyses

Statistical analyses were performed using one-way analysis of variance (ANOVA) to compare the microtensile bond strength between groups, followed by a Tukey's pair-wise comparison to detect any significant difference between two groups;  $p < 0.05$  was considered statistically significant. Data were normally distributed with equal variance and were analyzed using STATA 14.0 and ggplot2 software.<sup>22,23</sup>

### RESULTS

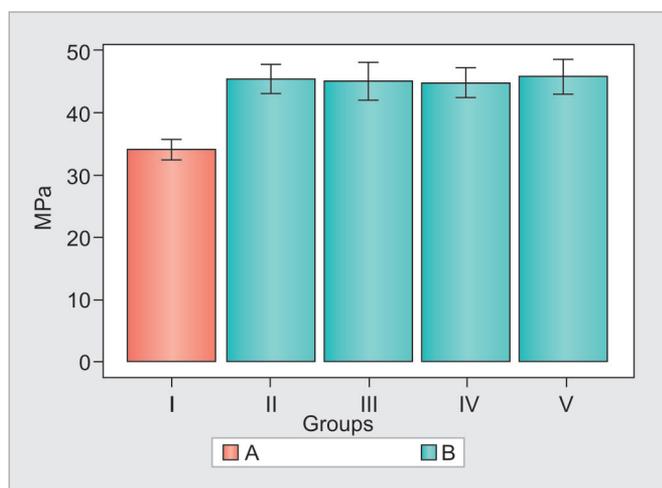
The microtensile bond strength of 242 bars was measured in this study. Of note, 8 bars from group I (immediate bonding after 35% hydrogen peroxide bleaching) were lost while being mounted to the Instron fixture due to weak bonding. In these situations, the composite was easily separated from dentin and thus, we were not able to test these samples. The results of the microtensile bond strength test for each group are detailed in Table 1. The mean microtensile bond strength of group I ( $34.17 \pm 10.78$ ) was significantly decreased relative to values from all other groups ( $p < 0.05$  for all comparisons). Results of Tukey's *post hoc* test of the five groups are indicated in Graph 1. Specific comparisons of the mean microtensile bond strength between all groups are shown in Table 2 and reveal a significant difference in microtensile bond strength between group I and all other groups [ $F(4, 1073.81) = 3.54, p < 0.01$ ].

Notably, the group that received bleaching followed by a 1-week delay of bonding (i.e., group II;  $45.36 \pm 16.57$ ) showed similar values to the group that did not receive bleaching (i.e., group V;  $45.83 \pm 19.32$ ) and no statistical difference was observed between these two groups ( $p > 0.05$ ). The mean microtensile bond strength values for the group that received bleaching followed by immediate treatment of sodium ascorbate and immediate bonding

**Table 1:** Descriptive statistics of mean microtensile bond strength (MPa)

Groups	Number of samples	Mean (MPa) ± SD	Minimum	Maximum
I	42	34.17 ± 10.78	11.73	56.75
II	50	45.36 ± 16.57	18.27	86.54
III	50	45.06 ± 20.91	16.71	117.28
IV	50	44.73 ± 16.85	14.50	95.74
V	50	45.83 ± 19.32	14.54	95.39

SD: Standard deviation



**Graph 1:** Treatment with sodium ascorbate following bleaching with hydrogen peroxide restores microtensile bond strength (MPa). Graph depicts mean microtensile bond strength (MPa) for each group tested. Statistical significance was determined by two-way ANOVA followed by Tukey's *post hoc* comparisons,  $p < 0.05$

of composite resin (i.e., group III;  $45.06 \pm 20.91$ ) was significantly higher than the group that received immediate bonding after bleaching (i.e., group I;  $p = 0.03$ ). Thus, immediate treatment with sodium ascorbate reverses the negative effects of hydrogen peroxide bleaching on microtensile bond strength.

## DISCUSSION

Patients who have time constraints due to travel plans or important events may be discouraged when a restorative procedure has to be delayed for at least 1 week following bleaching treatment. This may negatively affect patients' enthusiasm for further esthetic treatment plan options. An agent that can reverse the temporary weakening effects of the bleaching agent on the bond strength would be a very practical solution as it would save time and be more convenient for both the patient and dentist.

In the present study, our results demonstrate that application of 35% sodium ascorbate significantly improved the microtensile bond strength of composite-resin interface when applied immediately after in-office bleaching with 35% hydrogen peroxide. This difference was observed despite a noticeable degree of variation within each group, which is likely attributable to the fact that dentin bonding can be highly variable within one sample. Regardless, our results show a clear difference in the microtensile bond strength of samples treated with sodium ascorbate immediately following bleaching. Thus, we reject our null hypothesis that application of sodium ascorbate at any point after hydrogen peroxide bleaching will not significantly improve the microtensile bond strength of the composite resin-dentin interface when compared with hydrogen peroxide bleaching alone.

**Table 2:** Comparison of mean bond strength among the five treatment groups

Groups	Difference	Lower 95% CI	Upper 95% CI	$p > t$
II vs I	11.19	1.18	21.21	0.020
III vs I	10.90	0.88	20.92	0.025
IV vs I	10.57	0.55	20.59	0.033
V vs I	11.67	1.65	21.69	0.013
III vs II	-0.30	-9.87	9.28	1.000
IV vs II	-0.63	-10.20	8.95	1.000
V vs II	0.47	-9.10	10.05	1.000
IV vs III	-0.33	-9.91	9.24	1.000
V vs III	0.77	-8.81	10.34	0.999
V vs IV	1.10	-8.47	10.68	0.998

I = Bleaching + Immediate Bonding of composite; II = Bleaching + Delayed Bonding of composite; III = Bleaching + 35% Sodium Ascorbate application + Immediate Bonding of composite; IV = Bleaching + 35% Sodium Ascorbate application + Delayed Bonding of composite; V = Immediate Bonding of composite with no Bleaching (control)

Sodium ascorbate is available as an over-the-counter vitamin supplement. While it can cause gastrointestinal symptoms when ingested in very high doses, it is entirely safe to be utilized topically.<sup>24</sup> It has been used as an antioxidant treatment due to its capability to neutralize and reverse the oxidizing effect of peroxide-containing agents.<sup>4</sup> Many studies have succeeded in reversing the weakened bond strength of bonded composite resin using lower percentages of sodium ascorbate solution that were used in this study; however, this required longer application times that varied between 10 minutes and 6 hours.<sup>2,4,11,15,25</sup> Clinically, there are situations in which sufficient time between bleaching treatment and application of composite resin to dentin cannot be attained. This includes the sealing of a root canal immediately after internal bleaching, restoration of a posterior noncarious lesion, or restoration of an occlusal cavity while a patient is under home-bleaching therapy. Our methods involved two applications of a sodium ascorbate solution for 1 minute each, which is a shorter and more clinically feasible treatment. Freire et al<sup>9</sup> demonstrated that the reaction between the oxide residuals and antioxidants usually reaches its summit in about a minute, which highlights the importance of the number of sodium ascorbate applications rather than the duration of application. Thus, only increasing the contact time of the sodium ascorbate solution may not be sufficient to eliminate residual oxide. The results of our study confirm that repeated, short applications of sodium ascorbate is an effective approach to reverse the weakening effects of bleaching agents, such as hydrogen peroxide.

Previously, Freire et al<sup>10</sup> suggested that treatment with sodium ascorbate at the same concentration as the hydrogen peroxide, i.e., used for bleaching can reverse the negative effects of hydrogen peroxide on bond strength, which is consistent with the results from this study. In support of this, studies that used 10% sodium ascorbate were successful at reversing the weakening effects of

10% hydrogen peroxide on composite bond strength.<sup>4,26</sup> Similarly, an improvement in composite bond strength was observed in several studies that used 10% sodium ascorbate to reverse the action of 10 to 17% carbamide peroxide,<sup>11,13,14,19,20,25,27-31</sup> a bleaching agent that dissociates to 3.35% hydrogen peroxide and 6.65% urea.<sup>32</sup> In contrast, studies that used 10% sodium ascorbate to reverse the effects of 35% hydrogen peroxide failed to show significant improvements in bond strength.<sup>16,17</sup> Consistent with previous studies, our results demonstrate that improvements in composite bond strength can be achieved when the concentration of sodium ascorbate is equivalent to or surpasses the actual concentration of hydrogen peroxide present in the bleaching agent.

A study by Türkün et al<sup>33</sup> found that the application of 10% sodium ascorbate hydrogel produced stronger shear bond strength of enamel when compared with the negative control (nonbleached teeth). These results were attributed to the ability of sodium ascorbate to neutralize residual oxides, regardless of their source (i.e., as by-products of bleaching or from normal atmospheric oxygen).<sup>33</sup> However, in our study, we observed no difference in bond strength between groups that were treated with sodium ascorbate (groups III and IV) and those that did not receive sodium ascorbate treatment, including samples that did not undergo bleaching at all (group V). This suggests that the weakened bond strength observed due to bleaching can be restored with sodium ascorbate treatment but cannot exceed normal levels (that of unbleached samples). One difference between our study and that by Türkün et al<sup>33</sup> was the tooth substrate that was tested. Whereas Türkün et al<sup>33</sup> tested the effects of sodium ascorbate on bond strength in enamel, the focus of our study was on dentin. Other studies also showed consistent and more favorable outcomes of antioxidant treatment on enamel substrate compared with those that utilized dentin substrate.<sup>16,18,34</sup> The different structure and different bonding mechanisms between the two substrates could explain the disagreement in these findings. However, while the bleaching agent is applied on the enamel layer, it travels through enamel pores and reaches dentin, where most of the chemical reaction of the bleaching process takes place.<sup>4</sup> Dentin can act as a reservoir to trap oxygen, i.e., released as a by-product of the bleaching reaction.<sup>8</sup> Thus, it is important to consider the effects of sodium ascorbate treatment on composite resin bonding to dentin as this can be affected by components applied directly to the enamel layer.

In our study, we utilized hydrogen peroxide as a bleaching agent as this is commonly used for in-office bleaching. This approach usually requires one to two visits to the dental office.<sup>35,36</sup> Other investigators have studied the effects of carbamide peroxide, which is commonly used for home bleaching and takes 2 to 5 weeks to achieve

optimum results.<sup>37</sup> Correspondingly, the use of hydrogen peroxide as a bleaching agent has been reported to yield results 2.8 times faster than carbamide peroxide.<sup>38</sup> For this study, it was presumed that patients who are choosing in-office bleaching over the home-bleaching regimen might be more concerned about the duration of their treatment. Therefore, in the context of applying composite resin for restoration procedures, reducing treatment time by 1 to 2 weeks with the use of sodium ascorbate may make a bigger impact on patients' treatment of choice. In addition, the use of 35% hydrogen peroxide has been shown to be more harmful to resin infiltration than carbamide peroxide; thus, it seemed more relevant to study hydrogen peroxide bleaching agent in particular.<sup>39</sup>

Similar to previous studies, we observed a significant reduction in bond strength when composite was bonded immediately after 35% hydrogen peroxide bleaching.<sup>6,40-42</sup> In contrast, delaying the bonding procedure by 1 week following bleaching with 35% hydrogen peroxide restored the original bond strength, which is consistent with the findings from other studies.<sup>43,44</sup>

To limit the number of variables, the present study evaluated a single bonding agent, one concentration of antioxidant solution, and one application method on microtensile bond strength of the composite–dentin interface. It would be beneficial if each bleaching kit included a solution that could reverse the effects of bleaching. While we observed beneficial effects from sodium ascorbate treatment under the parameters in our study, further laboratory studies should be conducted to test different concentrations of bleaching agents with different concentrations of sodium ascorbate solution before clinical trials are commenced. Other important aspects to consider for further investigation include the stability of tooth color upon treatment with sodium ascorbate, as we observed that the clear, leftover sodium ascorbate solution turned a dark orange color an hour after it was mixed. This color instability could affect the final result of the bleaching treatment and should be further studied.

## CONCLUSION

The results of our study demonstrate that use of 35% hydrogen peroxide as a bleaching agent temporarily weakens the bond strength of the composite resin–dentin interface. A 1-week delay in the bonding procedure can restore the original bond strength. Similarly, treatment with 35% sodium ascorbate immediately following bleaching with 35% hydrogen peroxide also restores the original bond strength. Therefore, treatment with a 35% sodium ascorbate solution (2 applications for 1 minute each) is an effective and time-efficient solution to reverse the compromised bonding that results from bleaching with 35% hydrogen peroxide.

## CLINICAL SIGNIFICANCE

Our findings demonstrate significant improvement of composite bond strength after a very short application of sodium ascorbate when used at the same concentration as that of the hydrogen peroxide bleaching agent. This will allow better bonding of composite resin following hydrogen peroxide bleaching treatment and improve the chair-time efficiency for dentists and patients, helping to increase patient retention.

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