Acta Odontologica Scandinavica, 2011; 69: 287–291

informa
healthcare

ORIGINAL ARTICLE

Effect of antioxidant treatment on the shear bond strength of composite resin to bleached enamel

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Abstract

Introduction. This study examined the antioxidant treatment on the shear bond strength of composite resin to enamel after bleaching with two different bleaching systems. ***Materials and methods.*** Seventy flat enamel surfaces were prepared from freshly extracted human molars using a low speed diamond saw. Then the specimens were divided into seven random groups ($n = 10$) to apply different procedures; namely, bleaching with White Smile and bonding with composite resin (G1), bleaching with White Smile, treatment with ascorbic acid and bonding with composite resin (G2), bleaching with White Smile, immersing in artificial saliva for 2 weeks and bonding with composite resin (G3), bleaching with Opalesence and bonding with composite resin (G4), bleaching with Opalesence, treatment with ascorbic acid and bonding with composite resin (G5) and bleaching with Opalesence, immersing in artificial saliva for 2 weeks and bonding with composite resin (G6). Another group was used as a control group. Shear bond test was performed on all specimens and data were analyzed using one way ANOVA and Bonferroni's test ($p < 0.05$). ***Results.*** Bond strengths of bleached specimens were significantly lower than those of non-bleached specimens. No statistical difference was found in bond strength between the bleached and non-bleached groups when the antioxidant treatment was carried out. ***Conclusion.*** Ten per cent ascorbic acid treatment was found to be an effective method to reverse the compromised bond strength.

Key Words: *Bleaching, shear bond strength, antioxidant treatment, ascorbic acid, enamel*

Introduction

Vital tooth bleaching procedures are generally used in esthetic dentistry to treat discolored teeth [1]. Following the bleaching process, patients often require additional aesthetic interventions such as the replacement of old restorations and application of laminate veneers to restore esthetic deficiencies [2].

However, a number of studies have shown that in-office or at-home bleaching procedures adversely affect the bond strength of composite to the acid-etched enamel when bonding is performed immediately after the bleaching process [3–7].

It is reported that this is related with the presence of residual hydrogen peroxide in the inter-prismatic spaces as well as in the dentinal matrix and tubules [8,9]. These can prevent adequate infiltration of the bonding agent into the dental structures and also inhibit its polymerization [10]. Additionally, the presence of residual free radicals in the dental structure may interfere with the propagation of vinyl free radicals during light-curing of the adhesives, resulting in premature chain termination and incomplete polymerization [4,10]. Biocompatible reducing agents (e.g. ascorbic acid and sodium ascorbate) neutralize residual free radicals via a redox reaction. This can be explained by the antioxidant ability of reducing agents [11].

Several studies have proposed the use of antioxidant agents after the bleaching procedure to eliminate compromised bond strength [2,4,12–16]. If antioxidant treatment of bleached enamel before bonding reverses the reduced bond strength of composite resin, it may thus be a viable alternative to the delayed restorative procedure after bleaching.

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(Received 23 July 2010; accepted 19 January 2011)

ISSN 0001-6357 print/ISSN 1502-3850 online
DOI: 10.3109/00016357.2011.568958

The hypothesis of the study was that the application of the ascorbic acid solution to bleached enamels provided a bond strength that was equivalent to that of non-bleached enamels.

Materials and methods

Seventy freshly extracted molars were used in the study. After the removal of soft tissue, teeth were stored in distilled water at room temperature (for a maximum period of 1 month) and the water was changed weekly to avoid bacterial growth. Enamel surfaces were obtained by trimming the labial surfaces of the crown section to create enamel slabs. The slab dimensions were 4 mm × 4 mm × 4 mm, providing a flattened surface area of 16 mm^2. The slabs were embedded in a self-curing polyester resin in a polyvinylchloride ring mold of 2.1 cm in diameter. The slab surfaces were flattened using decreasing grits (400, 600, 1200) of aluminium oxide abrasive papers under water irrigation. Afterwards the specimens were divided into seven random groups ($n = 10$) to apply different procedures (Table I).

- *Group 1*: Specimens were bleached with White Smile and bonded with composite resin.
- *Group 2*: Specimens were bleached with White Smile, treated with 10% ascorbic acid and bonded with composite resin.
- *Group 3*: Specimens were bleached with White Smile, immersed in artificial saliva for 2 weeks and bonded with composite resin.
- *Group 4*: Specimens were bleached with Opalasence and bonded with composite resin.
- *Group 5*: Specimens were bleached with Opalasence, treated with 10% ascorbic acid and bonded with composite resin.
- *Group 6*: Specimens were bleached with Opalasence, immersed in artificial saliva for 2 weeks and bonded with composite resin.
- *Group 7*: Control, no treatment. Specimens were not bleached and bonded with composite resin.

Table I. Groups and protocols used in the study.

G1	Bleaching with White Smile + Composite restoration
G2	Bleaching with White Smile + 10% ascorbic acid treatment + Composite restoration
G3	Bleaching with White Smile + 2 week immersion in artificial saliva + Composite restoration
G4	Bleaching with Opalasence + Composite restoration
G5	Bleaching with Opalasence + 10% ascorbic acid treatment + Composite restoration
G6	Bleaching with Opalasence + 2 week immersion in artificial saliva+ Composite restoration
G7	No treatment + Composite restoration

Bleaching procedure

Two commercial brands of bleaching agents, White Smile (White Smile GmbH, Birkenau, Germany) and Opalasence Utah (Ultradent, South Jordan, Utah, USA) containing 35% hydrogen peroxide (HP), were used in this study. Bleaching gels were placed onto slabs at 1–2 mm thickness for 15 min and were replaced three times.

Ascorbic acid treatment procedure

A solution containing 10% sodium ascorbate (L(+) ascorbic acid sodium salt) was prepared by a method in which 98% sodium ascorbate (Sigma, Canton, MA) was dissolved in purified water by mixing at room temperature (ph:7.5). Ascorbic acid was applied to the enamel slabs for 10 min following the bleaching process. The specimens were then rinsed with distilled water and dried with compressed air.

Bonding procedure

Following the etching procedure with 35% phosphoric acid (3M Scotchbond TM Etchant, 3M Dental Products, St Paul, MN), the adhesive (Single Bond TM, 3M Dental Products) was applied onto the slabs. To apply the composite resin, a teflon mold with a height of 5 cm and a diameter of 3 cm was placed over the slab for the application of two layers of composite resin (Filtek Z 250, 3M Dental Products), using LED (LEDMax 550, Benlioğlu Dental, Ankara, Turkey) for 10 s on each layer.

The materials used in this study are listed in Table II.

Shear bond strength testing

Shear bond strengths of the samples were analyzed in a universal test machine (Instron, Lloyd LRX, Fareham, UK) at a crosshead speed of 1 mm/min. The load required to dislodge each slab was recorded in MPa.

The normality assumptions were controlled by Shapiro-Wilk test. The data were normally distributed; thus, parametric statistics were used to evaluate the data. A one-way ANOVA was used at a confidence interval of 95%. All statistical analyses were carried out using SPSS software (SPSS Version 13.0). The mean values and standart deviations were used as the descriptive statistics. Statistical significance was set at $p \leq 0.05$.

Results

Mean shear bond strength values and differences between the groups are listed in Table III and Figure 1. According to the one-way ANOVA results,

Table II. The list of materials and manufacturers that were used in the study.

No	Material name	Manufacturer	City	Country
1	Opalescence Boost	Ultradent	South Jordan	USA
2	Whitesmile	Whitesmile GmbH	Birkenau	Germany
3	Filtek Z250	3M Dental Producs	St Paul, MN	USA
4	3M Scotchbond TM Etchant	3M Dental Products	St Paul, MN	USA
5	Single Bond TM	3M Dental Products	St Paul, MN	USA
6	Ascorbic acid	Sigma	Canton, MA	USA

the control group which were unbleached (G7; 25.6 MPa) showed the highest mean retention values compared with the other groups. Ascorbic acid applied groups (G2 and G5) followed the highest mean retention values (23.3–23.0 MPa). There were significant differences between the ascorbic acid applied and non-applied groups (Figure 1). G1 and G4 groups showed significantly low bond strength values (bonded with composite resin immediately after bleaching) and they were lower than the other groups ($p < 0.05$). The artificial saliva immersed (delayed bonding) groups (G3 and G6) showed higher bond strength values than non-immersed groups (G1 and G4). The control group (G7) showed the highest bond strength of all groups. There was no statitistical difference between the two bleaching agents.

Discussion

A shear bond strength test is the common procedure used for the evaluation of the bonding efficiacy of dental materials [17–19]. This method was used in the present study to compare the impact of different treatment modalities on enamel composite shear bond strength subsequent to a bleaching procedure [16].

The results of the study indicated that part of the research hypothesis was acceptable. Antioxidant treatment to the bleached enamels provided higher bond strength than the non-treated group but lower bond strength than the control group.

The results of this study showed that there was an effective reaction between 35% HP and sodium ascorbate. This can be explained by the mechanism of action of the bleaching agents as well as that of the antioxidants. Peroxides produce an oxidation reaction in the molecular chains of organic pigments by means of free radicals, as a result of which the chains are broken one by one and the pigments lose their color [20]. Antioxidants are substances which react with free radicals, such as oxygen generated by the degradation of hydrogen peroxide, neutralizing them in the structure in which they are entrapped [21].

In the study, the resin material had significantly lower bond strengths to bleached enamel specimens than it did to non-bleached specimens. When ascorbic acid was applied to the enamel slabs, the bond strength of the resin to the bleached enamel surface was maintained at a level equivalent to non-bleached surfaces. This result seemed to indicate that the cause of reduced bond strength was due to the oxygen ions produced by the bleaching agent [22]. Ascorbic acid and its salts are well known antioxidants. They are capable of reducing a variety of oxidative compounds, particularly free radicals [23–25]. Many studies have demonstrated the potential protective effect of ascorbic acid against HP-induced damage in biological systems [23,26,27]. In the present study, the ascorbic acid applied specimens indicated enhanced bond strength. Thus, the oxidation reducing effect by the ascorbic acid treatment was validated. Usage of ascorbic acid in the oral cavity was preferred because of its reducing ability and

Table III. Mean values of loads required to dislodge the crowns.

Groups	Diff*	Mean (MPa)
G1	A	17.37
G2	C	23.33
G3	B	19.83
G4	A	17.84
G5	C	22.96
G6	AB	18.97
G7	D	25.55

*Means for groups in non-homogeneous sub-sets are displayed with different letters. Sub-set for alpha = 0.05.

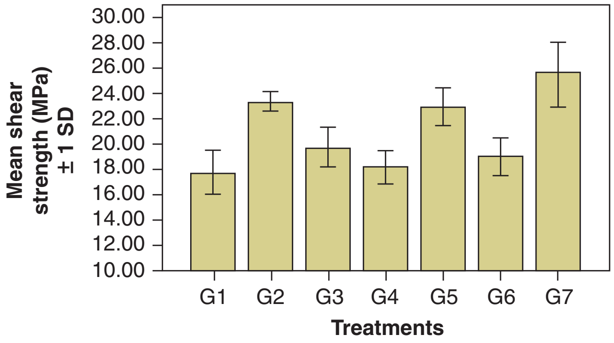

Figure 1. Shear bond strengths to enamel ($p \leq 0.05$).

safety. After obtaining the 10% ascorbic acid, it was used immediately because storing an ascorbic solution for a long time is difficult. It is stored in a dark, low temperature and non-metallic container to prevent it from losing its original form.

Many studies related with the antioxidant treatment investigated the shear bond strength of composite to dentin or bovine enamel which was submitted to 10% carbamide peroxide bleaching agent. According to the results of these studies, it is concluded that antioxidant treatment immediately after bleaching is effective in reversing the bond strength [2,12,16,28–31]. The difference between this study and the others is that other studies were using 35% HP bleaching agent and enamel.

The commonly used bleaching agents are 35% HP for clinic and 10% carbamide peroxide (CP) for home. The 10% CP decomposes to produce HP at a concentration of ~ 3.5% [32]. This is 10-times lower than the concentration used in the present study. This can explain why the studies using 10% sodium ascorbate reported reversion of the reduced bond strength after dental bleaching with 10% CP [2,13,14,33]. However, after dental bleaching with 35% HP followed by application of 10% sodium ascorbate as the antioxidant agent, bond strength increased but did not return to the original values for non-bleached controls [34].

In the study of Freire et al. [34], it was observed that the reaction between HP and sodium ascorbate was fast and that 5 min was long enough for the antioxidant to reduce the bleaching gel. In this study, a longer reaction time such as 10 min did not have a positive effect for increasing the bond strength as the contol group.

As Freire et al. [34] stated in their study, the results of this study have great clinical significance, as many patients need to have restorations replaced or undergo esthetic procedures soon after dental bleaching.

In the present study, as expected, the bond strength of the composite resin to bleached tooth was decreased immediately after bleaching. Some authors suggest delay in restorative procedures after bleaching to avoid compromised bond strength problems [14,23,35–39]. Although there are different recommendations about the post-bleaching time periods, 2 week delays for bonding procedures after bleaching are suggested by the authors. In the present study, delayed bonding showed increased bond strength values as expected.

The action mechanism of bleaching agents is based on a complex oxidation reaction releasing oxygen free radicals which penetrate through the porosities of the enamel prism to the dentin and chemically break down organic molecules which pigment the dentin into carbon dioxide and water released together with the nascent oxygen [39–43]. Diminished shear strength after bleaching may be related to residues from HP degradation on the tooth surface. HP acts as a strong oxidizing agent through the formation of free radicals, reactive oxygen molecules and anions [44–46]. On the other hand, demineralization of outer surface decreases microhardness of hard tissues. This may result in reduced surface energy values and will change adhesion properties [43–45]. Bleaching agents change the original ratio between organic and inorganic components of the tissues and increase their solubility [44].

In the present study 10% sodium ascorbate was applied to the enamel slabs for 10 min. Shorter durations (5 min) should be evaluated in future studies. Moreover, failure mode and scanning electron microscope evaluations of enamel composite interface should be carried out in future studies.

Conclusions

(1) Bleaching with 35% HP adversly affected the enamel composite bond strength when the bonding procedure was performed immediately after bleaching.
(2) Ten per cent ascorbic acid treatment of enamel following bleaching reversed the reduced composite enamel bond strength.
(3) Adhesive restorations to enamel should be delayed at least for 2 weeks if patients have a history of in-office bleaching with 35% HP.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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