

Original Article

Post-bleaching application of an antioxidant on dentin bond strength of three dental adhesives

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ABSTRACT

Background: Antioxidizing agents have recently been suggested to compensate decreased bond strength of resin materials to bleached tooth tissues. This study compared the shear bond strength (SBS) of three different adhesives on bleached dentin immediately after bleaching, bleached/delayed for 1 week, and bleached/applied antioxidantizing agent.

Materials and Methods: The dentinal surfaces of 132 intact extracted molars were prepared and divided into 12 groups. The following adhesives were investigated: Optibond FL (OFL) (three-step etch-and-rinse), Optibond Solo Plus (two-step etch-and-rinse), and Optibond all-in-one (OA) (one-step self-etch) (Kerr, Orange, USA). Unbleached dentin groups (groups 1-3) were prepared as negative controls (NC). The remainder surfaces (groups 4-12) were bleached with 20% Opalescent PF (Ultradent, USA). Specimens were bonded immediately after bleaching (groups 4-6), after 1 week (groups 7-9), or after using 10% sodium ascorbate (SA) gel (groups 10-12). Subsequent to bonding of composite resin, the samples were tested for SBS and analyzed using Kruskal-Wallis and Mann-Whitney tests ($\alpha=0.05$).

Results: Regarding control groups, OA showed the highest SBS among the studied adhesives ($P<0.05$). The SBS decreased for the adhesives after bleaching except for OFL. No statistically significant difference in SBS were noted when the SA and delayed bonding groups were compared with their similar NC groups ($P>0.05$) except the of delay bonding with OA.

Conclusions: The findings suggest that bond strength of resin to bleached dentin may be affected with the adhesive system. Reduced SBS to bleached dentin can be amended by the use of SA as an antioxidantizing agent. However, the amount of reversed bond strength subsequent to applying antioxidant might be related to the kind of dental adhesive.

Key Words: Antioxidant, bond strength, bleaching, dentin, etch-and-rinse adhesives, self-etch adhesives

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INTRODUCTION

The esthetics of anterior teeth is an important consideration in contemporary dental practice. Vital bleaching procedures are considered as one of the most conservative treatments, since they do not need

any reduction in tooth structure.^[1,2] Tooth color is dependent on the intrinsic tooth color and extrinsic stains. The intrinsic tooth color is a function of reflection or absorption of received light by tooth structure.^[1] Tooth bleaching is performed by extra-coronal technique for vital and non-vital teeth, and intra-coronal and sometimes intra-/extra-coronal for non-vital teeth.^[3] Usually, peroxide components are used for tooth bleaching.^[2,4]

Although bleaching agents clearly result in a lighter color in teeth, they have side effects too: pulp sensitivity,^[1,2] possible alterations in tooth structure,^[4] microleakage of restorations,^[5] external root resorption,^[3] and decreased bond strength of resins.^[6]

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Decreased bond strength in treatments in which resin bonding agents are used is of utmost importance: direct and indirect esthetic veneers or restorations using composite resins and porcelain.^[7] Different reasons have been reported for such a decrease in bond strength, including changes in tooth surface roughness and increase in tooth porosity;^[7] residual oxygen which inhibits resin polymerization through free radical mechanism; decrease in hardness;^[4] increase in microleakage;^[5] changes in the mechanical properties of tooth structure, including fracture resistance^[8] and fracture toughness,^[9] which is a factor involved in resisting crack formation and changes in it leads to decreased bond strength.^[4]

Some studies have reported a short period of decrease in bond strength of composite resin to enamel and dentin immediately after in-office and at-home bleaching procedures,^[10-12] which has been attributed to two reasons. First, the bleaching agent remaining in the organic matrix of enamel and the collagen matrix of dentin and dentinal tubules can break into water and oxygen. The oxygen released interferes with infiltration of resin tags into the pores of the etched dentin. Second, oxygen acts as an inhibitor and interferes with resin polymerization through free radical mechanism.^[7]

Several methods have been recommended to compensate decreased bond strength subsequent to tooth whitening, including delayed bonding (DB) or a waiting period of 24 hours up to 3 weeks, which is the most common and easiest procedure; elimination of surface enamel; use of acetone-containing adhesives; use of alcohol on tooth surfaces; and use of antioxidizing agents such as gel or solution forms of sodium ascorbate (SA).^[13,14]

On the other hand, another factor which has a role in the bond strength of composite resin to dentin is the type of the adhesive system used for bonding. Some studies have shown that acetone-based adhesives might reverse the negative effect of bleaching on bond strength to enamel without any need to remove the superficial layer of enamel or delaying the bonding procedure. In addition, the ethanol present in ethanol-based adhesives has been recognized as an agent involved in increasing bond strength by decreasing the amount of water on the surface. The hydrophilic nature of these solvents (acetone and ethanol) might be more important in dentin due to inner moisture in dentin.^[15] Some researchers have suggested that the use of alcohol-based adhesives results in a higher bond strength compared with acetone-based adhesives

because alcohol interacts with water and oxygen to reverse the negative effects of oxygen. A study failed to demonstrate any differences in bond strength of these adhesives.^[16]

Some studies have investigated bond quality between etch-and-rinse and self-etch adhesives subsequent to bleaching.^[17-19] The results of all these studies and more recent studies indicate that bond strength compromise subsequent to dental bleaching is seen in all the etch-and-rinse or self-etching systems.^[9,17-20] A delay in bonding procedure reverses the bond strength decrease.^[9,16]

In recent years, SA as an antioxidant has been used to compensate bond strength compromise subsequent to tooth bleaching. In studies in which SA as an antioxidant have been used, dentin bond strength has enhanced to the level of that in the control groups.^[11,13,14]

According to the results of a study carried out by Yiu *et al.*, use of SA significantly compensates the decrease in bond strength to dentin in Single Bond adhesive only; however, it is not effective in the case of Excite adhesive. Therefore, it seems this clinical efficacy depends on the type of the adhesive used.^[20] Cadenaro *et al.* compared polymerization degree of three etch-and-rinse (Clearfil Protect Bond, One Step, Adper Scotchbond Multi Purpose) and one self-etch (Xeno III) adhesives bonded to dentin and did not report any significant differences between them.^[10] Shinohara *et al.* evaluated the effect of bleaching non-vital teeth on the shear bond strength (SBS) of composite resin with the use of three Single Bond (alcohol/water-based), Prime and Bond (acetone-based), and Clearfil SE Bond (water-based), and concluded that bleaching decreases the SBS regardless of the type of the adhesive used.^[12]

Although some authors have advocated the use of etch-and-rinse adhesives in comparison with self-etching ones subsequent to dental bleaching,^[17,18,21] no studies have compared the use of an antioxidant. Therefore, this study evaluated the potential of SA as an antioxidizing agent to compensate dentin bond strength decrease with the application of etch-and-rinse and self-etching dental adhesive systems compared with DB subsequent to at-home bleaching technique.

MATERIALS AND METHODS

The present study was carried out on 132 molars which had been extracted at most four months prior

to the study and had been preserved in normal saline solution at 4°C. The teeth had no previous restorations, caries, and cracks. One week before the experiment, all tooth surfaces were cleaned of any debris and soft tissues and immersed in 0.1% thymol solution; 24 hours before the experiment, the teeth were retrieved from thymol, rinsed, and stored in distilled water.

In all the specimens, the crown was separated from the root with a diamond bur under water spray. Then, the crown was mounted in cold-curing acrylic resin (Acropars, Marlic Medical Co, Tehran, Iran) in a manner in which the buccal surface of the tooth was level with the acryl and the horizon as much as possible. Buccal surfaces were trimmed until the dentin was exposed and then were ground on wet silicon carbide papers up to grit 800 to create flat dentinal surfaces. The specimens were randomly divided into 12 groups of 11 teeth each. The groups were treated as follows:

In groups 1-3 (negative controls=NC), Z100 composite resin was bonded to dentin surfaces with the adhesives Optibond FL (OFL) (three-step etch-and-rinse), Optibond solo plus (OSP) (two-step etch-and-rinse), and Optibond All-in-One (OA) (one-step self-etch) according to manufacturer's instructions (Kerr, Orange, CA, USA) [Table 1].

In groups 4-12, 20% carbamide peroxide gel (Opalescent PF 20%, Ultradent, South Jordan, UT, USA) was placed in direct contact with the prepared dentinal surfaces. To this end, similar plastic rings were prepared and fixed on enamel surfaces using cellophane; the rings were 5 mm in diameter and 2 mm in height. Then, bleaching gel was injected into the wells produced. After the rings were filled and it was made sure that no bubbles were present, they were covered with the second layer of cellophane to protect the bleaching gel from environmental contaminants and air.

Based on at-home bleaching technique, the bleaching agent was placed in contact with tooth surfaces for 6 hours a day for five consecutive days according to manufacturer's instructions. During the bleaching period, the specimens were kept in an incubator at 37°C at relative humidity. The bleaching agent was rinsed from tooth surfaces for 1 minute using a water spray after each bleaching regimen. Then, the specimens were stored in relative humidity at 37°C in an incubator.

Immediately after the bleaching procedures, bonding was carried out in the three positive control (PC) groups (groups 4-6) using the three adhesive systems, OFL, OSP, and OA (Kerr, Orange, CA, USA) and

Table 1: Materials used in the study and mode of their applications according to the manufacturers' instructions

Materials compositions	Manufacturers' instructions	Material name and manufacturer
Optibond FL (three step, etch, and rinse adhesive) (Kerr, Orange, CA,USA)	<ol style="list-style-type: none"> 1. Etch with 37.5% phosphoric acid (15 seconds) 2. Rinse for (15 seconds) and dry (5 seconds) 3. Apply primer and rub for 15 seconds. Dry for 5 seconds 4. Apply adhesive in a uniform thin layer 5. Light cure for 30 seconds. 	Etchant: 37.5% H ₃ PO ₄ FL Primer:HEMA,GPDm, MMEP, Water, ethanol, CQ, BHT FL Adhesive: Bis-GMA, HEMA, GDMA, CQ, ODMAB,filler(fumedSiO ₂ , barium aluminoborosilicat, Na ₂ SiF ₆) coupling factor A174(48 wt% filled)
Optibond Solo Plus (two-step, etch, and rinse adhesive) (Kerr, Orange, CA, USA)	<ol style="list-style-type: none"> 1. Etch with 37.5% phosphoric acid (15 seconds) 2. Rinse (15 seconds) and dry (5 seconds) 3. Apply the adhesive and rub for 15 seconds. Dry for 3 seconds 4. Light cure for 20 seconds. 	Etchant: 37.5% H ₃ PO ₄ Adhesive:Bis-GMA, HEMA, GDMA, GPDM, ethanol, CQ, ODMAB, BHT, filler (fumed SiO ₂ ,barium aluminoborosilicate, Na ₂ SiF ₆), Coupling factor A174 (15 wt% filled)
Optibond All-in-One (one-step, self etch adhesive) (Kerr, Orange, CA, USA)	<ol style="list-style-type: none"> 1. Shake the bottle for 10 seconds, 2. Apply the adhesive and rub for 20 seconds, 3. Repeat the procedure, 4. Air dry lightly for 5 seconds, 5. Light cure for 10 seconds. 	Glycerol phosphate dimethacrylate, mono- and di-functional methacrylate esters, water, acetone, ethanol
Z100 Composite resin (3M ESPE)	Z100 composite resin applied in 2 mm layers. Each layer light cured for 40 seconds.	Bis-GMA, TEGDMA, Zirconium/Silica filler
Opalescent 20% PF (Ultra dent, USA)	Bleaching gel for at-home bleaching, 6h/d for 5 consecutive days.	Carbamid Proxide 20%, Potassium Nitrate, Fluoride (0.11%)
Sodium ascorbate gel (Appli Chem, Germany)	After preparing 10% hydrogel, the gel was applied in the access cavities for 6 hours and then rinsed.	Natrium-L-(+)-ascorbat (C ₆ H ₇ NaO ₆ M=198.11g/mol)

Bis-GMA: Bisphenol A diglycidyl methacrylate, BHT: Butylhydroxytoluene, CQ: Camphorquinone, GDMA: Glycerol dimethacrylate, GPDM: Glycerol phosphate dimethacrylate, HEMA: 2-hydroxyethyl methacrylate, MMEP: mono-2-methacryloyloxyethyl phthalate, ODMAB: 2-(ethylhexyl)-4-(dimethylamino)benzoate, TEGDMA: triethylene glycol dimethacrylate

Z100 composite resin (3M ESPE, USA) according to manufacturers' instructions [Table 1].

The three DB groups (groups 7-9) were stored in relative humidity at 37°C for a week after bleaching. Then, bonding procedures were performed similar to what was explained before.

In SA groups, (groups 10-12) 10% SA gel was injected to the rings similar to the rings described for the bleaching procedure, and the specimens were stored under relative humidity at 37°C for six hours (equivalent to one day of bleaching regimen). Then, bonding was carried out in the manner previously described.

For bonding procedure, after the application of the adhesives according to manufacturer's instructions, transparent cylindrical molds were prepared, with a height of 4 mm and a diameter of 3 mm. The composite resin was placed inside the molds in a manner in which it had a convex surface so that air would not be trapped between the tooth surface and composite resin. Curing was carried out from three directions of top and two sides for 40 seconds from each side (a total of 120 seconds) using a light-curing unit (Coltolux 50, Colton/Whaledent, USA) at a light intensity of 480 mW/cm².

All the specimens were incubated at 37°C for 24 hours subsequent to the bonding procedure. Then, the plastic molds were cut away using scalpel blades #11. The specimens then underwent a 500-cycle thermocycling procedure (Mp Based, KARA 1000 Inc, Tehran, Iran) at 5°C/55°C with a dwell time of 20 seconds and a transfer time of 12 seconds.

Finally, the specimens underwent a shearing bond strength test using a universal testing machine (Dartec, HC10, Dartec Ltd, Stourbridge, UK). Each specimen was fixed on the jig in a manner in which the composite cylinder was parallel with the horizon, and the equipment blade was placed adjacent to the composite-tooth interface perpendicular to composite resin at a strain rate of 1 mm/min. The force was applied until the composite resin was detached from the tooth surface and the force was recorded in Newton (N). In order to convert the force to MPa, the value was divided into the composite resin surface area. Data were analyzed using Kruskal-Wallis and Mann-Whitney U-tests. ($\alpha=0.05$)

Additionally, the fractured surface of each specimen was analyzed under a stereomicroscope at $\times 16$ (MBC-

10, St. Petersburg, Russia) and the mode of fracture was determined. Fracture modes were classified as follows:

- Adhesive: Fracture at enamel-composite interface;
- Cohesive: Fracture in the restorative material alone or enamel alone;
- Mixed: A combination of adhesive and cohesive fractures.

RESULTS

Means and standard deviations for the groups under study are summarized in Table 2. Based on the results of the present study, the highest and lowest bond strength values were observed in the NC group with OA adhesive and in the PC group with OSP adhesive, respectively. Except for the NC groups, in which OA had a significant higher bond strength compared with OFL and OSP, in all the other groups, OFL resulted in the highest bond strength. The lowest bond strength in all the groups was related to OSP.

Two-by-two comparisons of the groups under study with the relevant *P* values also are presented in Table 2. In the SA groups, the differences between OFL and OA, between OA and OSP, and between OFL and OSP were significant.

In comparison of the bond strength of each adhesive in different techniques [Table 2], regarding OFL, the differences between the SA group and the other groups including NC, PC, and DB were significant.

In relation to OSP, only the differences between the NC and PC groups were significant.

In relation to OA, the differences between PC group and the other three groups were significant.

The frequency of different fracture modes are shown in Table 3. As the table indicates the highest number of adhesive, failures was observed in the PC groups.

Table 2: Shear bond strength values (MPa) for the three adhesive systems at different studied procedures (Mean \pm SD)

Group adhesive	NC	PC	DB	SA
OFL	17.22 \pm 5.22 ^{Aa}	15.18 \pm 5.01 ^{Aa}	17.04 \pm 6.70 ^{Aa}	22.66 \pm 7.46 ^{Ba}
OSP	15.74 \pm 4.66 ^{Aa}	5.40 \pm 1.42 ^{Bb}	11.54 \pm 4.56 ^{Aa}	13.92 \pm 3.06 ^{Ab}
OA	34.50 \pm 12.06 ^{Ab}	11.04 \pm 4.46 ^{Bc}	14.40 \pm 3.24 ^{CeA}	20.94 \pm 3.96 ^{Dc}

NC: Negative control, PC: Positive control, DB: Delayed bonding, SA: Sodium ascorbate, OFL: Optibond FL, OSP: Optibond solo plus, OA: Optibond All-in-one. Means followed by different letters show statistical differences: ($\alpha = 0.05$) Capital letters: Comparison of each procedure for each adhesive (row), Lower case letters: Comparison of adhesives at each procedure (column)

Table 3: Different failure modes in the study groups (n=11)

Adhesives groups	OFL	OSP	OA
	NC-PC-SA-DB	NC-PC-SA-DB	NC-PC-SA-DB
Adhesive	2-5-3-3	4-8-5-5	1-5-2-3
Cohesive	3-3-4-2	2-0-1-2	3-2-3-3
Mixed	6-3-5-6	5-3-5-4	7-4-6-5

OFL: Optibond FL, OSP: Optibond solo plus, OA: Optibond All-in-one, NC: Negative control, PC: Positive control, DB: Delayed Bonding, SA: Sodium ascorbate

The highest numbers of dentin cohesive failures were observed in self-etch adhesive.

DISCUSSION

In the present study, parametric analyses should have been used; however, non-parametric tests were used since data variances were heterogeneous. According to the results, the decrease in the bond strength of composite resin to bleached enamel in the PC groups was significant compared with the NC groups in the case of OSP and OA adhesives. However, in the case of OFL, although there were differences between the PC and NC groups with a higher bond strength in the NC group, the differences were not statistically significant. Previous studies have demonstrated the negative effect of bleaching on the bond strength of composite resin to enamel and dentin.^[10,22] Several theories have been proposed to explain the reasons for decrease in bond strength. One of the theories purports that the bleaching agent can break into water and oxygen in the collagen matrix and dentinal tubules. The release of oxygen can interfere with the penetration of resin into the etched dentin,^[22] Oxygen can result in the formation of an oxygen-inhibited layer on the surface of the bonding agent in the vicinity of environmental air. It has been reported that inhibition of polymerization can also occur in the sub-superficial layer of the bonding agent, which supports the resin tags. The thickness of the oxygen-inhibited layer depends on the chemical composition of the monomer, the activation method, and the resin viscosity.^[17] It should be pointed out that the presence of water in dentin might interfere with the polymerization of the adhesive resin.^[17,23] Some studies have shown that carbamide peroxide does not change oxygen accumulation on enamel surface; therefore, the decrease in bond strength cannot be attributed to accumulation of oxygen. However, it has been reported that dentin can act as an important reservoir for oxygen.^[24] Montalvan *et al.* reported that

hydrogen peroxide molecules move in tooth structures and denature proteins, which results in an increase in the permeability of tooth structures, facilitating the movement of ions in tooth structure.^[16]

Some other studies have attributed bond strength decrease to changes in the mechanical properties of dentin or denaturing and instability of proteins which form the fibrillar matrix of dentin.^[10] Toto and Hisamitsu attributed the bond strength decrease to changes in the organic content of dentin.^[6]

In the present study, in groups delay bonding, bond strength increased. However, in the case of OA adhesive, a 1 week delay was not sufficient to compensate the decrease in bond strength, which is consistent with the results of a study carried out by Cadenaro *et al.*^[10] They reported that in multi-step adhesives, contrary to simplified adhesives, delaying the restorative procedure in bleached enamel for 24 hours or two weeks can restore composite resin polymerization degree to that in the control group, which might be attributed to the fact that adhesives can react with oxygen in different ways based on their chemical composition. Furthermore, studies have shown that simplified adhesives with lower viscosity and higher concentrations of hydrophilic monomers (such as HEMA) have a greater tendency to form thicker oxygen-inhibited layers.^[10] It has been reported that during the delay period before the bonding procedure, peroxide remnants are removed by dissolution in water; saliva has the same effect in clinical conditions.^[14]

In the present study, the SBS, in groups in which SA gel was used after bleaching and before composite resin application, was significantly different from that in the PC group. OFL had the highest bond strength in this respect. However, in the etch-and-rinse groups, the bond strength was not significantly different from the DB groups. This phenomenon was attributed to the fact that SA not only neutralizes the oxidative effects of bleaching agents but it allows for the polymerization of the adhesive before its premature termination by restoring the altered reduction potential of dentin as well.^[11]

Of the groups bleached by SA, only OA adhesive resin was not able to completely neutralize the negative effects of bleaching on SBS, which might be attributed to the duration of application, intermittent use, and the type of the antioxidant in addition to the chemical composition of the adhesive. Kaya *et al.*

reported that the use of the antioxidant for a longer period of time yields more satisfactory results;^[22] however, further studies are necessary on the subject. The results of a study indicated that the use of SA to reverse the decrease in bond strength to dentin is effective in the case of Single Bond. However, it is not effective with Excite adhesive, which is consistent with the results of the present study, indicating that the efficacy of the antioxidant depends on the type of the adhesive used. The reason might be attributed to the fact that the bleaching agent not only inhibits polymerization of the adhesive, but it also might influence the collagen network of dentin, resulting in denaturing and relative instability of the dentin organic matrix. However, more detailed and accurate studies are required to determine to what extent the surface and deep changes of the substrate are important in this respect.^[10]

A number of studies on bond strength have suggested that the effect of bleaching agents on adhesives depends on the extent of demineralization brought about by self-etch and etch-and-rinse adhesives.^[10] Furthermore, the extent of susceptibility might depend on the type of the solvent used in the adhesive agent; in this context, ethanol- or acetone-based adhesives are compared with water-based adhesives. Barghi and Godwin reported that acetone- or ethanol-based adhesives can reverse the effect of bleaching agents due to their ability to absorb water.^[15] However, Cadenaro *et al.* who carried out a study on the polymerization degree of one acetone-based adhesive (One step) and three water/alcohol-based adhesives (Clearfil Protect Bond, Scotch Bond Multi Purpose, Xeno III) after bleaching the enamel reported no differences between the adhesives.^[10] The results of that study confirm the results of a study carried out by Shinohara *et al.* who reported that the use of acetone-, ethanol-, or water-based adhesives cannot reverse the effect of bleaching agents on bond strength.^[12] In the present study, there were no differences in the bond strengths of OFL (water/alcohol-based), OSP (alcohol-based), and OA (water/acetone-based) after bleaching and none could increase the bond strength to that of the NC group, although OFL yielded the best results and the difference between PC and NC was not significant. In the PC group, the differences in the bond strength between the three adhesives were statistically significant. Kimyai and Valizadeh reported that Single Bond (water/alcohol-based) cannot reverse the negative effects of bleaching agents.^[11] Finally, it does not appear that the type of the solvent in the

adhesive has a noticeable effect on reversing the bond strength subsequent to bleaching.

The adhesives evaluated by Shinohara *et al.* can be compared from the self-etch and etch-and-rinse viewpoints since they applied two etch-and-rinse (Single Bond and Prime Bond) and one two-step self-etch (Clearfil SE Bond) adhesives.^[12] Therefore, it can be concluded that there is no difference between etch-and-rinse and self-etch adhesive systems in reversing the effects of bleaching agents. Cadenaro *et al.*^[10] reported that etching and rinsing procedures cannot eliminate the remnants of oxygen from the surface, consistent with the results of the present study. On the other hand, Moule *et al.*^[18] purported that application of etch-and-rinse adhesives, such as Single Bond, contrary to Clearfil SE Bond adhesive, can prevent decreases in bond strength to enamel. They explained this phenomenon by the possibility that bleaching changes enamel surface or produces deposits that interfere with the mechanism of the chemical bond of this adhesive. It should be noted that in the study carried out by Moule *et al.*, the samples were stored in water for three days after bleaching,^[18] followed by the bonding procedure, which can be considered a DB procedure.

The adhesives in the present study can be compared in the NC groups, too, regardless of the bleaching process. From this viewpoint, OA demonstrated the highest bond strength to dentin; however, some studies have revealed a low efficacy for all-in-one adhesives *in vitro*.^[25,26] It has been reported that these simplified adhesives act as a semi-permeable membrane, permitting the passage of water at interfacial surfaces, which results in the hydrolytic breakdown. On the other hand, recent studies have reported increases in bond strength of these adhesives with time.^[27] In the present study, OFL demonstrated better results compared with OSP; however, the difference in the NC group was not significant. Some previous studies^[26,28,29] have not reported significant differences in bond strength to dentin between these two adhesives.

In the present study, evaluation of failure modes from PC toward NC groups revealed decreases in adhesive failure percentages and increases in mixed and cohesive failure percentages. This trend was seen in all the three adhesives and was consistent with increases in the mean bond strength values in the three NC, DB, and SA groups compared with the PC group.

Finally, it should be pointed out that *in vitro* studies have some limitations and the majority of variables in the oral cavity during bleaching *in vivo* do not hold *in vitro*. In addition, factors such as dentin age, dentin thickness, dentin depth, sclerosis of the dentinal tubules, and the oral cavity conditions, such as the presence of natural saliva, which is an important clinical variable, do not hold *in vitro*; these variables greatly influence the bonding and bleaching procedure of dentin.^[23] Further studies on the chemical composition of adhesives and their possible interactions with bleaching agents and antioxidants are necessary; in addition, the duration of the application and the number of applications of antioxidants should be evaluated.

CONCLUSIONS

Under the limitations of the present study, it was concluded that:

1. Two-step etch-and-rinse OSP and one-step self-etch adhesives OA cannot reverse the decrease in bond strength to dentin subsequent to bleaching, while three-step etch-and-rinse adhesives OFL compensate the bond strength decrease to some extent.
2. A delay of one week with etch-and-rinse adhesives cannot restore the bond strength to that of the unbleached group; however, this fact did not hold for self-etch adhesive.
3. Although application of SA gel along with both etch-and-rinse and self-etch bonding systems can restore the bond strength to normal, the three-step etch-and-rinse adhesive yielded more satisfactory results.

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