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Effect of Antioxidants on Shear Bond Strength of Ceramic Veneers to Office Bleached Enamel

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Abstract

Purpose: Several studies confirmed the effectiveness of antioxidants in reversing the compromised bond strength of composite resin bonded immediately after bleaching enamel with 10% carbamide peroxide. This study aimed to investigate the effect of two different antioxidants surface treatments on shear bond strength of ceramic veneers bonded to enamel immediately after 25% hydrogen peroxide office bleaching.

Materials and Methods: 35 sounds freshly extracted human third molars were used, utilizing both buccal and lingual enamel surfaces for bonding. The samples were randomly divided into seven groups (n=10). The enamel surfaces were bleached with 25% hydrogen peroxide except the last group (control) which was bonded to enamel without bleaching. In group 1, enamel bonding was performed immediately after bleaching. In groups 2-5, enamel surfaces were treated immediately after bleaching with either sodium ascorbate or α-Tocopherol solutions in two concentrations (10 and 25%) prior to bonding. while in group 6; bonding was delayed for two weeks after immersion in artificial saliva. Specimens were subjected to shear bond strength test at cross-head speed of 0.5mm/min. The fracture analysis was observed using stereomicroscope. Results were analyzed using one-way analysis of variance (ANOVA) and Tukey tests at a significant level of P= 0.05.

Results: ceramic veneers bonded immediately to enamel treated with both concentrations of sodium ascorbate showed higher shear bond strength than veneers bonded to enamel treated with α-Tocopherol solutions. However, no significant difference was detected between the two antioxidants. Enamel treatments with both antioxidants following bleaching showed no significant difference in the bond strength than the bonding immediately after bleaching.

Conclusion: Delayed bonding to enamel after office bleaching still the best method to reverse the compromised bond strength.

Keywords: bleaching, antioxidant, sodium ascorbate, α-Tocopherol, Ceramic veneer, Shear bond strength

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Introduction

Many clinicians consider vital tooth bleaching as the first treatment option in severely discolored teeth because it is the most conservative approach. However, there is a high possibility of a negative influence of this procedure on any further dental treatments such as bonding to the tooth structure. The reduction in the bond strength of the adhesive restorations bonded to enamel immediately after tooth bleaching has been stated in many studies [1-3].

Some techniques have been suggested to enhance the bond strength of previously bleached teeth such as removing the superficial layer of enamel or treating the bleached enamel surface with alcohol before bonding the restoration [1,4,5]. However, delaying the bonding procedure for a period of time is considered the best solution, since the reduction of bond strength has been shown to be reversible [6-10]. Lai et al introduced the use of an antioxidant (sodium ascorbate) as a surface treatment which can immediately reverse the compromised bond strength of bleached teeth with hydrogen peroxide or teeth treated with sodium hypochlorite [3]. Many studies confirmed the effectiveness of 10% sodium ascorbate in reversing the compromised bond strength of previously bleached enamel with 10% carbamide peroxide and bonded to resin composite [11-13]. In 2009, Sasaki et al found that another antioxidant, which is α-tocopherol, was highly effective in reversing the compromised bond strength after bleaching [14]. Most of the studies mentioned previously examined the effect of antioxidants on shear bond strength of enamel to composite resin or ceramic veneers following home bleaching (10% carbamide peroxide) [11-13]. The objective of this study was; to investigate the effect of two percentages of sodium ascorbate (vitamin C) and α-Tocopherol antioxidant (vitamin E) enamel surface treatments on the shear bond strength of ceramic veneers bonded to office bleached enamel (25% hydrogen peroxide).

Materials and Methods

Thirty-five sounds human third molars were used in this study. They were free of caries, cracks, abrasion facets, fluorosis, and damage from extraction. Following extraction, teeth were washed thoroughly and stored in distilled water with 0.05% thymol solution. The roots were removed approximately 2mm below the cemento-enamel junction using a slow-speed diamond saw (Isomet 2000, Buehler, Lake Buff, Illinois, USA) under a water-coolant spray. The crown of each tooth was then sectioned in the mesio-distal direction in order to use both the buccal and lingual enamel surfaces for the bonding procedures. Self-cure acrylic resin (Ortho resin, Dentsply, UK) was loaded in polyvinyl chloride (PVC) cylindrical molds which was fabricated and used for mounting the teeth. Each sectioned specimen either buccal or lingual surface was embedded in the acrylic resin while it was soft so that the buccal or lingual surfaces facing upwards for the bonding procedure. The embedded enamel surfaces were grounded and polished using 240-, 400-, 600-grit silicon carbide paper (Buehler, Lake Bluff, Illinois, USA) to create a uniform flat, polished surface that is flushed with the acrylic resin. This step also aids in grinding the enamel surface to be ready for the bonding procedure. The samples were inspected with light microscope (Steeozoom 5, Bausch & Lomp, USA) to ensure that the enamel surface was intact and no dentin was exposed. Then, the samples were randomly divided into seven groups (n=10), as shown in (Table 1).

Preparation of the Ceramic Samples

Seventy discs of a lithium disilicate glass-ceramic, shade A1, (IPS e.max Press, LT A1, Ivoclar Vivadent, Liechtenstein) were fabricated using a circular custom-made stainless-steel mold with a thickness of 0.7mm and width of 3mm using lost wax and heat pressed techniques. The discs were ultrasonically cleaned for 15 min in ethanol and deionized water then randomly divided into the tested groups.

Preparation of the Antioxidants

Sodium ascorbate and α-Tocopherol solutions were prepared as described by Sasaki et al [14] in two concentrations as shown in Table 2. The materials for

Preparing the solutions were obtained from Sigma-Aldrich® Chemical Company/England.

Bleaching Procedure

Enamel specimens in groups 1-6 were bleached with 25% hydrogen peroxide (Zoom Advanced, Discus Dental) as the manufacturer instructions. Five samples, only from each group, were bleached in each bleaching session to ensure the complete light coverage on the samples. Each sample completed four sessions of 15 minutes each, giving a total of one-hour office bleaching. After the bleaching procedure, all specimens were washed with distilled water and placed in a labeled container with fresh distilled water.

Application of Antioxidant

After bleaching, all specimens in the test groups from 2-6 were subjected to treatment with antioxidant solutions. The assigned antioxidant solution was applied onto the surface of each enamel specimen for 10 minutes as the methodology of Turkun et al [15].

Bonding Procedure

The surfaces of the ceramic discs that bonded to the tooth structure were etched with 4.9% hydrofluoric acids (IPS ceramic etching gel, Ivoclar, Schaan, Liechtenstein) for 60 seconds. Then, silane (Monobond-S, Ivoclar, Schaan, Liechtenstein) was applied using a micro brush on the ceramic surface and left to react for 60 seconds and dried gently with a stream of air.

Before bonding, a piece of adhesive tape was punched with a circular, 3mm in diameter. The hole was securely adapted to the center of the flattened portion of the enamel to limit the

Table1: Groups used in the study

Groups	Bleaching Treatment	Antioxidant Treatment	Bonding
1	25% HP	None	Immediately after bleaching
2	25% HP	10% SAS	After Treatment
3	25% HP	25% SAS	After Treatment
4	25% HP	10% ATS	After Treatment
5	25% HP	25% ATS	After Treatment
6	25% HP	None	After two weeks immersion in artificial saliva
7	None	None	After two weeks immersion in artificial saliva

* HP: Hydrogen peroxide. SAS: Sodium ascorbate solution. ATS: α-tocopherol solution

Table 2: Antioxidants Surface Treatment

Groups	Treatment Agent	Composition	PH
2	10% sodium ascorbate solution	sodium ascorbate and water	8
3	25% sodium ascorbate solution	sodium ascorbate and water	8
4	10% α-Tocopherol solution	α-Tocopherol and alcohol	5.5
5	25% α-Tocopherol solution	α-Tocopherol and alcohol	5.5

bonding surface. The demarcated enamel surface was etched with phosphoric acid 37% (etching gel, Ivoclar, Schaan, Liechtenstein) for 30 seconds, washed and dried. The total-etch adhesive system (Syntac®, Ivoclar Vivadent, Schaan, Liechtenstein) was applied according to the manufacturers' instructions. Syntac® Primer was applied to the enamel surface with a disposable tip brush provided by the system kit for 15 seconds then dried gently. Then, Syntac® Adhesive was applied to the enamel surface with a new brush for 10 seconds and dried gently as a second layer. After that both the enamel and the ceramic surfaces were ready to apply the hydrophobic adhesive (Heliobond, Ivoclar Vivadent, Schaan, Liechtenstein) which was applied by a disposable brush then dried gently.

A customized stainless-steel mold was fabricated with thickness of 0.5 mm to stabilize the ceramic veneer disc. A 3mm circular hole was made in the center of this mold, the same size as the ceramic disc. The mold was placed in the center of the punched area of the enamel surface so that the two holes (on the mold and the treated enamel surface) were in intimate contact. The peripheries of the PVC were stabilized with the mold using wax. Variolink® Veneer (Ivoclar Vivadent, Schaan, Liechtenstein) was placed in the mold hole followed by the treated ceramic disc. The excess cement was removed with a disposable micro-brush. A thin glass slap with a length of 75mm, width of 25mm and thickness of 1mm was placed on the top of the ceramic disc and stabilized with a static constant load (weight of 200 grams) in each side of the slap. The ceramic discs were light cured vertically for 40 seconds according to the manufacturer instructions with a halogen previously calibrated light curing device (Elipar™ 2500 Halogen Curing Light, 3M™ ESPE™), then the glass slap and mold were gently removed and the light was circumferentially rotated until the total time of curing was 120 seconds. The excess of resin cement was removed with a scalpel blade.

After bonding, the samples were stored in distilled water at 37°C for at least 24 hours then subjected to 1000 cycles in thermocycling apparatus (Thermocycler THE1100/1200, SD Mechatronik) between bathes of 5 and 55°C with a dwell time of 30 seconds. The specimens in groups six and seven were immersed in 250ml of artificial saliva at 37°C for two weeks. Artificial saliva was prepared as described by Cavalli et al [9].

Shear Bond Strength Testing and Mode of Bond Failure

The specimens were subjected to a shear bond strength test using a universal testing machine (Instron 8500, England) with a load cell of 10 KN. A knife edge rod with a width of 0.5mm was applied at the interface of the ceramic veneer disc with the enamel at cross-head speed of 0.5mm/min.

The fracture sites along the enamel-ceramic disc interface were observed under the stereomicroscope (Stereo 80 Widefield Microscope, Swift, CA, USA) to determine the modes of bond failure. Fracture modes were classified as adhesive, cohesive or mixed and were defined as follows: adhesive failure showed no sign of enamel fracture or remnants of ceramic on the tooth. Cohesive fractures showed complete fracture of enamel or resin, while mixed samples showed both adhesive and cohesive failures.

One-way analysis of variance (ANOVA) was used to compare the mean values across the seven groups, followed by Tukey HSD to compare among the seven groups. A p-value of <0.05 was considered as statistically significant.

Results

The mean shear bond strength for all experimental groups is presented in (Table 3) and expressed in (Figure 1).

There was no significant difference between delaying bonding for two weeks after bleaching and bonding without any bleaching procedure (P=0.999). Bleached enamel immersed in saliva for two weeks before bonding showed significantly higher bond strength to ceramic veneers than enamel surfaces bonded immediately after bleaching without antioxidant surface treatment (P=0.000). ceramic veneers bonded immediately to enamel treated with both concentrations of sodium ascorbate showed higher shear bond strength than veneers bonded to enamel treated with α-Tocopherol solutions. However, no significant difference was recorded between the two antioxidants (Table 4). Also, ceramic veneers bonded to beached enamel surfaces treated with both antioxidants at the different concentrations, showed significantly lower shear bond strength than ceramic veneers bonded to the delayed bonded group.

The distribution of failure across the seven groups was given in a (Table 5). From the Table, it was noticed that most the adhesive failures in this study were at the ceramic/resin cement interface.

Discussion

The bonding of ceramic veneers immediately after enamel bleaching in the present study showed significantly reduced bond strength than when the veneers bonded to unbleached enamel. This result was stated in many similar previous studies [16-19]. The bleaching agents release free radicals as nascent oxygen and hydroxyl or peri-hydroxyl ions when they are applied to the dental structure [19]. These free radicals may interfere with the resin infiltration into the etched enamel or inhibit the polymerization of the resin [20-23]. Changes in proteins and in mineral content of most superficial layers of enamel after bleaching may also responsible for the reduction in bond strength [23].

The results of the present study showed that there were no significant differences between the shear bond strength of veneers bonded to unbleached enamel and those delayed bonding for two weeks after bleaching. This might be explained by the possible morphological or structural repair in bleached enamel during the waiting period before bonding while teeth were restored in artificial saliva [9,11]. Several studies found no significant difference between using an antioxidant surface treatment immediately after bleaching procedure and delaying the restorative bonding for at least two weeks [14,24,25]. These studies explained their findings to the use of sodium ascorbate which allows free-radical polymerization of the adhesive resin to proceed without premature termination by restoring the altered redox potential of the oxidized bonding substrate, thus reversing the compromised bonding [3]. Since Vitamin C and its salts are non-toxic and are widely used in the food industry as antioxidants, it is unlikely that their intraoral use will create any adverse biological effect or clinical hazard [11]. However, the result of this study showed no significant difference between treating the enamel with antioxidant and the immediate bonding after dental bleaching. This could be attributed to the difference in concentration of bleaching agents used in this study and the other studies. It was found that hydrogen peroxide produces more morphological changes and more loss of calcium and phosphorus in enamel than carbamide peroxide. This might reflect on enamel bond strength [26].

Although treating enamel surfaces after bleaching with 10% sodium ascorbate in this study did not produce significant higher bond strength to resin cement than other treatment modalities, it recorded the highest bond strength among the antioxidant groups. Shear bond strength gained in this study after enamel treatment with 10% Sodium ascorbate (23.01 MPa) was within the acceptable range reported in the literature (between 16 and 24 MPa), partially exceeding the cohesive strength of enamel [27,28]. Using sodium ascorbate after bleaching might be promising in cases where bonding has to be performed immediately to ensure better bond strength than bonding immediately without any surface treatment. This recommendation is also supported by the mode of failure as seen by the stereomicroscope. The ascorbic acid-treated specimens both concentrations showed a 100% adhesive failure between the resin cement and the ceramic

Table 3: Mean, Standard Deviation and Standard Error of Shear Bond Strength of Bleached Enamel to Ceramic Veneers

Groups		N	Mean	SD	Std. Error	95% Confidence Interval for Mean		Min	Max
						Lower Bound	Upper Bound		
(1)	**Im B**	10	18.44	4.25	1.34	15.40	21.47	11.52	26.17
(2)	**10% SAS**	10	23.01	5.19	1.64	19.30	26.73	17.06	33.30
(3)	**25% SAS**	10	21.97	5.96	1.88	17.71	26.23	16.53	35.79
(4)	**10% ATS**	10	18.25	4.61	1.46	14.95	21.55	11.12	28.00
(5)	**25% ATS**	10	16.83	4.06	1.28	13.93	19.73	12.09	24.34
(6)	**Del B**	10	31.86	7.86	2.49	26.24	37.49	17.78	41.58
(7)	**No Bl**	10	33.18	9.78	3.09	26.19	40.18	21.62	49.24
	Total	70	23.36	8.61	1.03	21.31	25.42	11.12	49.24

*Im B: Immediate bonding after bleaching procedure; SAS: Sodium ascorbate solution antioxidant surface treatment; ATS: Alfa-Tocopherol solution antioxidant surface treatment; Del B: Delayed bonding procedure for two weeks after bleaching; No Bl: Bonding to enamel without bleaching.

Table 4: Post Hoc Tests (Tukey HSD- multiple range tests) Showing the Means in Homogenous Subsets

Group	Subset for α = 0.05	
	1	2
5	16.83	
4	18.25	
1	18.44	
3	21.97	
2	23.01	
6		31.86
7		33.18
Sig.	.308	.999

*group1: Immediate bonding after bleaching procedure; group2:10% Sodium ascorbate solution antioxidant surface treatment; group3: 25% Sodium ascorbate solution antioxidant surface treatment. group4:10% Alfa-Tocopherol solution antioxidant surface treatment. group5:25% Alfa-Tocopherol solution antioxidant surface treatment; group6:

Delayed bonding procedure for two weeks after bleaching; group7: Bonding to enamel without bleaching.

Figure 1: Mean Shear Bond Strength Values of the Different Tested Groups.

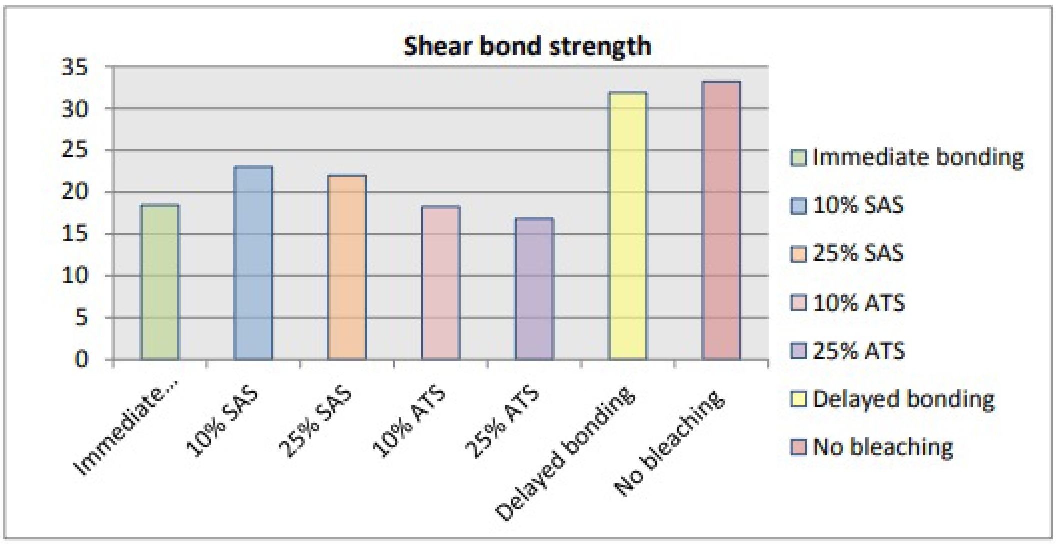

Table 5: Mode of Fracture of the Different Test Groups

Mode of Failure		Group							Total
		1	2	3	4	5	6	7	
Adhesive	% within Group	70.0%	100.0%	100.0%	60.0%	60.0%	90.0%	70.0%	78.6%
Cohesive	% within Group	.0%	.0%	.0%	10.0%	10.0%	10.0%	.0%	4.3%
Mixed	% within Group	30.0%	.0%	.0%	30.0%	30.0%	.0%	30.0%	17.1%
Total	% within Group	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

*group1: Immediate bonding after bleaching procedure; group2:10% Sodium ascorbate solution antioxidant surface treatment; group3: 25% Sodium ascorbate solution antioxidant surface treatment. group4:10% Alfa-Tocopherol solution antioxidant surface treatment. group5:25% Alfa-Tocopherol solution antioxidant surface treatment; group6: Delayed bonding procedure for two weeks after bleaching; group7: Bonding to enamel without bleaching.

disc with the enamel surface was completely covered with the resin cement. As a result, the oxidation reducing effect by the ascorbic acid treatment was validated. An ascorbic acid solution has an etching potential and highly acidic which may enhance the micromechanical retention of the resin. In other words, ascorbic acid was effective in maintaining the bond strength of the resin material not only by reducing the residual oxygen, but also by etching the tooth surface [19].

Although Sasaki et al claimed that α-Tocopherol antioxidant was effective in reversing the compromised bond strength of resin cement to enamel after bleaching, this was not the case in this study [14]. Ceramic veneers bonded to enamel surfaces treated with α-Tocopherol showed the least values of SBS in comparison with other groups in the study. This might be attributed to its physical properties; it has semi-viscous texture which may interfere with its complete wettability to the enamel surface [29]. Thus, this might affect its ability to remove the free oxygen radicals from enamel. Farther investigation is needed; increasing the application time might contribute to its ability to reverse the compromised bond strength after bleaching.

Conclusions

Within the limitation of this in-vitro study, the following conclusion was drawn:

1. Bonding ceramic veneers immediately after enamel bleaching with 25% hydrogen peroxide showed significantly lower bond strength than bonding veneers to unbleached enamel.

2. The compromised bond strength of ceramic veneers to enamel, bleached with 25% hydrogen peroxide was reversible, after two weeks immersion of enamel in saliva before bonding.

3. There was no significant difference between bleached enamel surfaces wither treated with any antioxidant or bonded immediately after bleaching without treatment.

4. Among all the antioxidants used in this study, 10% sodium ascorbate showed high shear bond strength values which might be a promising material in reversing the reduced bond strength after enamel vital bleaching.

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