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The Effect of Carbamide Peroxide Bleaching Gel Containing Remineralization Agents on the Bond Strength of Universal Adhesives to Enamel

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Abstract

Background: *The aim of this study was to examine the effect of carbamide peroxide bleaching gel containing remineralization agents on the bond strength of universal adhesives to enamel.*

Materials and Methods: *One hundred and thirty five extracted human third molars were divided into five groups to receive treatments during 14 days, as follows: no bleaching treatment (control group); 10% carbamide peroxide (CP); 10% CP containing 0.11% fluoride; 10% CP containing CPP-ACP; and 10% CP containing CPP-ACP and 0.11% fluoride. The buccal surfaces of all teeth were etched with 37% phosphoric acid, and each group was devided into three subgroups to receive the adhesive resins: All Bond Universal; Scotchbond Universal and Adper Single Bond 2. Then restored teeth were sectioned to create resin–enamel beams. These beams were subjected to the micro-tensile bond strength (µTBS) test, and assessed for failure mode under scanning electron microscopy.*

Results: *The highest mean µTBS of the composite resin to enamel was observed in the control group (25.9 MPa) and the lowest in the fluoride-containing bleaching group (17.2 MPa). Adper Single Bond 2 adhesive subgroups have the highest µTBS (19.7 MPa) and All Bond Universal adhesive subgroups have the lowest µTBS (16.8 MPa).*

Conclusion: *Oxygen negatively affects the polymerization of resins and adhesives. In cases where the teeth have been bleached, it is suggested waiting at least two weeks after the bleaching before completing an enamel bonded restoration to minimize the presence of remaining incorporated oxygen in the enamel. Inclusion of CPP-ACP in a fluoride containing bleaching agent minimizes the negative effect of the fluoride.*

Keywords: *Bleaching agents; remineralization agents; bond strength; universal adhesives.*

Introduction

Tooth bleaching is becoming increasingly popular in dental clinics for its aesthetic effect.[1] External bleaching with agents containing carbamide peroxide is widely used to whiten discolored teeth. However, their negative impact on dental hard tissues is controversial.[2] Side effects of bleaching such as surface softening, mineral loss, increased susceptibility to erosion or caries, reduced fracture stability or a decrease in abrasion resistance, and tooth sensitivity have been reported.[2,3] To reduce these negative effects, re-mineralization agents such as fluoride-containing solutions/compounds or casein phosphopeptide–amorphous calcium phosphate (CPP–ACP) have been introduced.[4,5]

Fluoride-containing bleaching gels have better whitening potential than gels not containing fluoride[6] and can accelerate the hardness of the bleached enamel.[5] Moreover, teeth treated with fluoride-containing bleaching gels have higher resistance to caries than teeth treated without bleaching[7] In addition, adding fluoride to bleaching material also reduces tooth sensitivity.[8,9]

Fluoride bleaching gels may facilitate the repair of the microstructural defects by the adsorption and precipitation of salivary components, such as calcium and phosphate. The susceptibility of bleached enamel to demineralization has been shown to be less following the use of a fluoride-containing carbamide peroxide bleaching gel.[2]

CPP–ACP contains milk protein and casein phosphopeptide;[10] it stabilizes and localizes ACP in dental plaque, and concentrate calcium and phosphate at the tooth surface.[11-13] By maintaining a high-concentration gradient of calcium and phosphate ions, CPP–ACP helps to suppress demineralization and promote remineralization of enamel by the deposition of apatite.[10,14] Furthermore, the CPP–ACP remineralizes human enamel subsurface lesions[11,14,15] and the remineralized enamel has been shown to be more resistant to subsequent acid attack.[5, 15]

When CPP-ACP is combined with fluoride toothpaste it shows higher remineralization potential.[16] By mixing fluoride with CPP-ACP complex, a significantly higher remineralization rate was seen compared with CPP-ACP or fluoride alone.[17] Mixing fluoride with CPP-ACP would appear to be logical to create synergic effects in preventing caries.[10] However, enamel mineralized with CPP-ACP and fluoride can result in reduced resin-composite bond strength.[11,12] The quality of adhesives in dentistry depends on various factors such as the type of adhesive used,[15] the clinical expertise of the dentist[18] and the tooth structure.[19]

Universal adhesives are a novel innovation in adhesive systems. Due to their ability to bond chemically to the tooth structure, it would be expected that bonding strength of universal adhesives to remineralized tooth structure would be stronger because of the teeth having an enriched mineral structure.[20,21] In vivo studies have shown that acid etching are effective methods for establishing a stable and predictable composite bond to enamel.[20] There are limited studies examining the effectiveness of adhesive systems on the durability of the bond between resin adhesive and enamel after using carbamide peroxide bleaching gels containing remineralization agents. The purpose of our study was to examine the effect of carbamide peroxide bleaching gel containing remineralization agents on the bond strength of universal adhesives to bleached enamel.

Materials and Methods

This in-vitro study was conducted on 135 intact human third maxillary molars without fracture, structural anomalies, caries, or previous restorations. The teeth were washed, scrubbed, scaled and cleaned with pumice. Remnants of blood, mucous, shreds of periodontal ligaments, plaque, and calculus were removed prior to being stored in saline solution at room temperature. The study protocol was approved by the Research Ethics Committee of Rafsanjan University of Medical Sciences, Iran (Number: IR.RUMS.REC.1394.127).

The buccal surfaces of teeth were polished with wet 320-grit silicon carbide paper to prepare standardized flat enamel surfaces for bleaching treatment and then adhesive bonding procedure. All enamel surfaces were examined by stereomicroscope (SMZ 1500, Nikon, Tokyo, Japan). Only samples with no defect were selected for study inclusion.

The samples were kept moist and stored in an incubator at 37°C and 100 per cent relative humidity throughout the experiment. The samples were randomly divided into the following five groups (27 teeth in each group): 1: Control group: The samples were untreated; 2: Bleach group: Specimens were treated with a 10% CP bleaching agent, Opalescence 10% (pH 6.0–6.5, Ultradent Products, Salt Lake, UT, USA); 3: Fluoridated bleach group: Specimens were treated with a fluoridated 10% CP bleaching agent, Opalescence PF 10% (Ultradent Products), containing 0.11% fluoride; 4: CPP-ACP bleach group: Specimens were treated with an experimental bleaching agent by adding CPP-ACP paste (GC Tooth Mousse, GC Corporation, Tokyo, Japan) into 15% CP and adjusting the pH to generate 10% CP containing CPP-ACP and 5: CPP-ACP and fluoridated bleach group. Specimens were treated with an experimental bleaching agent by adding 2% (w/w) sodium fluoride and CPP-ACP paste into 15% CP and adjusting the pH to generate 10% CP containing CPP-ACP and 0.11% fluoride. All the specimens, except the control group, were individually exposed to the assigned bleaching agents for eight hours over 14 consecutive days. The specimens were rinsed with air/water spray for 1-min to remove the bleaching agent. After the 14 days of bleaching, the specimens were maintained in an incubator at 37°C and 100% relative humidity for 14 days.

Bonding Procedure

The 27 teeth in each group were randomly divided into three subgroups with nine teeth in each group depending upon the bonding process. Subgroup 1: All Bond Universal adhesive (Bisco Inc, Schaumburg, IL, USA); subgroup 2: Scotchbond Universal adhesive (3M, ESPE, St. Paul, MN, USA); subgroup 3: A conventional etch & rinse adhesive, Adper Single Bond 2 (3M, ESPE). (Table 1)

The prepared specimens were etched with 37% phosphoric acid gel (3M, ESPE) for 15 seconds, thoroughly rinsed and gently dried. The adhesive systems were applied with a micro-brush on exposed surface of enamel and light cured according to the manufacturer's instructions.

Immediately after the adhesive was applied, a micro-hybrid resin composite (Filtek Z-250, 3M ESPE) was inserted inside a bipartite stainless steel matrix (4×3×3 mm) on treated enamel in two increments of 2-mm and each increment was light polymerized for 20 seconds, then the stainless matrix was removed. A light-emitting diode (LED) curing unit (Demetron A.2, Kerr Italia, S.p.A.) with an output of 1000 mW/cm^2 was used to polymerize the adhesive and the composite resin. Parallel sections measuring approximately one mm in width were made from the mesial to the distal surface and from the cervical to the occlusal surface using a cutting machine (Vafaei Co, Tehran, Iran) on each tooth. The sections were made at low speed under water-cooling to prevent stress induction at the bond interface. Each tooth was sectioned into nine specimens. Four specimens from each tooth were selected (36 sections in each subgroup) for analysis. The specimens with approximately 1.0 mm2 in cross section and 4.0 mm in length.

Table1. *List of materials used in this study*

Manufacturer	Main Components	Materials
Ultradent Products, South Jordan, UT, USA	10% carbamide peroxide gel, potassium nitrate and 0.11% fluoride ion	Opalescence PF 10%
Ultradent Products, South Jordan, UT, USA	15% carbamide peroxide gel, potassium nitrate and 0.11% fluoride ion	Opalescence PF 15%
Ultradent Products, South Jordan, UT, USA	10% carbamide peroxide gel	Opalescence 10%
3M ESPE St Paul, MN, USA	MDP, HEMA, dimethacrylate, resins,Vitrebond copolymer, filler, ethanol,water, initiators, silane	Scotchbond Universal
Bisco Inc. Schaumburg, IL, USA	MDP, bis-GMA, HEMA, ethanol,water, initiators	All-Bond Universal
3M ESPE St Paul, MN, USA	Bis-GMA, HEMA, dimethacrylate, methacrylate functional, copolymer of polyacrylic and polytaconic acid, water, alcohol, photoinitiator	Adper Single Bond 2
3M ESPE St Paul, MN, USA	Zirconia/silica filler, UDMA BisGMAand Bis-EMA resins	Filtek™ Z250
GC Corporation Tokyo, Japan	Glycerol, 5–10% casein phosphopeptide-amorphous calcium phosphate, pure water, zinc oxide, CMC-Na, xylitol,D- sorbitol, silicon dioxide, phosphoric acid, titanium dioxide, guar gum, sodium saccharin, ethyl-p-hydroxybenzoate, magnesium oxide, propylene glycol, butyl-p-hydroxybenzoate, propyl-p-hydroxybenzoate	GC Tooth Mousse

Micro-Tensile Bond Strength Test

For μTBS testing; each beam was fixed to a custom-made testing jig with cyanoacrylate glue (Universal Instant Adhesive; Henkel Adhesives Co. Ltd., Shantou, China) and tested in tension in a universal testing machine (Z010, Zwick/Roell, Ulm, Germany) at a cross-head speed of 0.5 mm/min until failure occurred. The cross-sectional area of each beam was measured to the nearest 0.01 mm with a caliper and then the bond strength values (MPa) were calculated by dividing the peak tensile load (N) at failure by the cross-sectional area in mm^2. To determine the failure modes, both surfaces of each beam were observed under an optical microscope (Olympus, Tokyo, Japan) at 20x magnification and classified as 1- cohesive failure in the resin composite or enamel; 2- adhesive failure in the resin enamel interface; or 3- mixed, combination of adhesive and cohesive failure in enamel and/or resin composite.

Data were statistically analyzed using SPSS software, version 21 (SPSS Inc, Chicago, IL, U.S.A.). Descriptive statistics including mean, standard deviation (SD), maximum and minimum of the micro-TBS were computed for each group. Normal distribution of the data was not confirmed using Kolmogorov-Smirnov test (P=0.001). Therefore, Kruskal-Wallis test was used for to compare all groups and Mann-Whitney test for pairwise comparisons in each storage times. The failure mode frequencies were reported. P<0.05 was considered statistically significant.

Results

The control group had the highest μTBS while the fluoride-containing bleaching group had the lowest bond strength. Moreover, pair comparisons of the study groups with respect to μTBS showed that bond strength differed significantly between all groups (p<0.05). As shown in Table 2, the highest bond failure pattern was of the adhesive type, and bond failure was higher in the fluoride group compared with the other groups.

Table2. *Micro-tensile bond strength means (μTBS; MPa), standard deviations, and failure mode of bleached treatment groups.*

	Failure Mode	Max	Min	Mean (SD)	Groups
	[47/40/13]	33.90	18.10	25.92(3.48)^{a}	Control
	[53/33/14]	30.20	16.20	22.17(3.35)^{b}	Bleach
	[57/27/16]	24.90	11.50	17.12(3.35)^{c}	Fluoridated bleach
	[53/33/14]	29.80	10.50	19.43(4.11)^{d}	CPP-ACP bleach
	[47/43/10]	30.38	16.40	21.91(3.42)^{b}	CPP-ACP and fluoridated bleach

SD, standard deviation

Failure mode: [adhesive failure/cohesive failure in resin composite or enamel/mixed failure] percentage of each failure mode.

*Different superscript lowercase letters indicate that there were statistically significant differences within each column ($p \leq 0.05$).

By comparing the bonding sub-groups, the highest μTBS was related to the Adper Single Bond 2 group and the lowest to the All Bond Universal group. (Table 3)

Table3. *Micro-tensile bond strength means (Mpa), standard deviations, and failure mode of bonding adhesive subgroups.*

Failure Mode			Mean (SD)	Min	Max	Adhesive Groups
[48/38/14]			16.82(5.37)^{a}	2.80	26.20	All bond universal
[66/24/10]			17.53(4.91)^{a,b}	4.70	25.00	Scotchbond universal
[40/44/16]			19.78(3.75)^{b}	13.20	27.10	Adper single bond 2

SD, standard deviation

Failure mode: [adhesive failure/cohesive failure in resin composite or enamel/mixed failure] percentage of each failure mode.

*Different superscript lowercase letters indicate that there were statistically significant differences within each column ($p \leq 0.05$).

Discussion

This study demonstrated that bleaching teeth using 10% carbamide peroxide gel reduced the μTBS of composite resin to enamel. Previous studies have also reported lower bond strength to enamel bleached with 10% carbamide peroxide gel.[22,23,24] Moreover, bleaching teeth using 16% carbamide peroxide gel significantly reduced bond strength.[25] Titley et al. showed that the existence of peroxide remains or materials containing peroxide on enamel surfaces interfere with resin bonds and consequently lead to bond failure.[26] Studies have confirmed that enamel retained oxygen inhibits bonding polymerization and resin expansion tags.[22,26] Some researchers have attributed bonding defects to changes in the surfaces and structures of enamel sub-surfaces such as loss of minerals and changes in the organic materials.[27] Bleaching agents create morphological changes such as porosity and changes in the enamel shape that could indirectly lead to weakness of the enamel as a result of reduced bond strength. Although retained oxygen is the main cause of reduced bond quality, structural defects in the enamel could also be involved in these changes.[26,27]

According to the results of our study, the μTBS of composite resin to bleached enamel was significantly lower in the fluoride-containing group compared to the group that was only bleached. In fact, the μTBS of the fluoride group had the lowest among all other groups. Various types of fluoride used for treating enamel surfaces reduced resin bond strength. These changes are related to the changes that fluoride makes in the enamel surface.[28] Fluoride reaction products on the enamel can decrease the wettability of the tooth surface which is conducive to lower bond strengths.[29] Enamel with a higher concentration of fluoride is also generally more resistant to acid etching. The results of our study are consistent with previous ones.[29,30] Interestingly, other studies have reported that exposing the etched enamel to fluoride before bonding orthodontic brackets did not affect the bond strength [31,32,33] except in high concentration[34] . We found that the μTBS in the bleaching groups containing CPP-ACP and fluoride-containing CPP-APC group was less than the bleaching group but the difference was not statistically significant ($p>0.05$). Adebayo et al. found that CPP-ACP did not have a significant effect on bond strength of bleached and unbleached enamel while the shear bond strength reduced slightly after CPP-ACP treatment.[25] Another study showed that CPP-ACP after bleaching does not inhibit the etching effect of phosphoric acid on the enamel and does not have a considerable effect on reducing bond strength compared with bleaching without CPP-ACP.[35] Meng et al. found that enamel remineralization with CPP-ACP is highly resistant against acid and could possibly interfere with the resin bond. Such side effects might be seen when using the novel form of CPP-ACP complex that includes fluoride 900 PPM.[12] Cehreli et al. also found that both self-etch and total etch adhesive systems showed slight but statistically significant reduction in bond strength in enamel treated with fluoride-containing CPP-ACP.[10] The combination of fluoride with CPP-ACP does not improve resin bond strength in self-etch and total etch systems. Moreover, CPP-ACP compounds without fluoride did not change shear bond strength,[10] and in some studies prophylaxis with CCP-ACP did not reduce the bond strength of etch-and-rinse bonding systems.[35,36]

In this study, the μTBS was higher in total-etch adhesive groups compared with universal ones. Among the universal adhesive groups, the μTBS of Scotchbond Universal was more than All Bond Universal, which is consistent with a similar previous study.[20] Moreover, McLean found that the bond strength of universal bonding is less than total etch, but the bond strength was not significantly different after six months.[37]

In our study, with respect to fracture pattern, adhesive fracture were found more often in the bleaching only, fluoride-containing bleaching and the CPP-ACP bleaching groups compared with the control group and with a higher frequency in the fluoride-containing group. Chuang et al. found that bleaching alone and fluoride-containing bleaching groups did not have a cohesive fracture pattern, but adhesive fracture was considerably higher in these two groups compared with the control group.[27]

Oxygen negatively affects the polymerization of resins and adhesives. In cases where the teeth have been bleached, it is suggested waiting at least two weeks after the bleaching to minimize the presence of remaining incorporated oxygen, before completing an enamel bonded restoration to minimize retained oxygen in the tooth structure. In addition, one study reported the use of a diode laser to minimize the enamel damage by bleaching agents.[38] Moreover, the use of fluoride-containing bleaching materials, especially those with higher fluoride percentage, should be minimized because of reduced bond strength. We also found that no significant difference was observed in the bond strength of universal adhesives to re-mineralized enamel compared to etch and rinse adhesives. However, this could be due to the limitation of the study being in vitro and relatively short in duration. Further studies are warranted.

Conclusions

A low concentration of carbamide peroxide is an effective dental bleaching agent. However, bleaching with this agent can be associated with demineralization of the treated enamel, quantitative mineral loss, reduction in adhesive bond strengths and tooth sensitivity. The addition of fluoride to the bleaching agent addresses some of these concerns but it also reduces bond strength. However, when CPP-ACP was added to the fluoridated bleaching agent the loss of resin bond strength was minimal compared to bleach alone.

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