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Influence of Prolonged Light-curing Time on the Shear Bonding Strength of Resin to Bleached Enamel

M Hussain • Y Wang

Clinical Relevance

The bonding strength of resin composite to bleached enamel can be enhanced by increasing the light exposure time of light-emitting diode units if bonding is delayed for 24 hours.

SUMMARY

This study evaluated the effect of prolonged light-curing time using a light-emitting diode unit (LED) on the shear bond strength of a resin composite to enamel immediately after bleaching. The enamel surfaces of human molars were divided into four groups: one control and three bleaching groups. One bleaching group (CP) was exposed to a 10% carbamide peroxide bleaching agent and bonded after 24 hours. The other two bleaching groups (HP) were bleached with a 38% hydrogen peroxide bleaching agent, then bonded either within one hour (HPA) or after 24 hours (HPB). All groups were subdivided into two subgroups and cured for two different times (20 or 40 seconds) with an LED unit. Shear bond strength (SBS) was tested with a universal-testing machine and the data were analyzed by ANOVA and post-hoc tests. Scanning electron micrographs of representative specimens were taken. A significant difference was seen between the control and HPA groups for both curing times (p=0.000). However, neither the CP nor HPB groups showed any significant differences compared with the control groups (p>0.05). Two-way ANOVA showed that a significant effect of the curing time factor was recorded for all groups (p=0.000). Prolonged curing time, using an LED unit with a light intensity of 500 mW/cm^2, increased resin-enamel bonding strengths for the control and bleached groups when bonding was performed after 24 hours of immersion in deionized water. However, the SBS was still compromised when bonding was performed immediately to enamel bleached with 38% HP.

INTRODUCTION

Bleaching systems have been received by the public as a more conservative and economical method for improving the appearance of the dentition. Hydrogen

Manal Hussain, DDS, MS, PhD student, School and Hospital of Stomatology, Wuhan University, Wuhan, Republic of China

*Yining Wang, DDS, PhD, professor, Key Laboratory for Oral Biomedical Engineering of Ministry of Education, School and Hospital of Stomatology, Wuhan University, Wuhan, Republic of China

*Reprint request: Luoyu Road 237, Wuhan, 430079, Republic of China; e-mail: wang.yn@whu.edu.cn

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peroxide (HP) or carbamide peroxide (CP) bleaching agents with different concentrations, formulations and pH have proven to be effective in tooth whitening. Carbamide peroxide is an adduct of urea and hydrogen peroxide, which, on contact with water, breaks down to urea and hydrogen peroxide. A 10% CP bleaching agent breaks down to approximately 3% HP and 7% urea. Hydrogen peroxide is a strong oxidant and can form free radicals by homolytic cleavage. It is capable of oxidizing a wide range of colored organic and inorganic compounds, causing decolorization and, hence, the bleaching of tooth substrates. There have been a number of reports on the interaction between bleaching agents and bonding strengths of resin composite to enamel.[1-4] Delaying the placement of resin composite restorations from one-to-three weeks after bleaching has been recommended by many researchers.[1-3] However, immediate resin composite restorations may be indicated after the bleaching procedure to achieve better esthetic results.[5]

Reduction of resin-enamel bonding strength immediately after bleaching has been observed in previous studies. This reduction was attributed to the inhibition of polymerization of the resin-based materials due to the presence of residual oxygen from the bleaching agents.[6-7] Several techniques have been suggested to overcome immediate post-bleaching compromised bonding strength, such as removal of the superficial layer of enamel,[8] surface treatment[9-10] and the use of alcohol-based adhesive systems.[11]

Until recently, composites have been polymerized almost exclusively with light emitted from a halogen light bulb. These types of light sources usually operate at light intensities between 400 and 800 mW/cm^2, and they polymerize composite within 40 seconds at depths of up to 2 mm.[12] LED light-curing units (LCUs), a solid-state light-emitting diode technology, have been proposed for light-curing dental materials to overcome shortcomings related to quartz-tungsten-halogen units (QTH). LEDs generate light by well-defined relaxation of excited electrons. The spectral output of blue LEDs fall conveniently within the absorption spectrum of the camphorquinone photoinitiator in the resin composite (400–500 nm). Several generations of LEDs have been introduced into the market, with different power densities ranging from 152 up to 2000 mW/cm^2. It has been reported that a correlation between power density and polymerization has been established with QTH lights.[13] Therefore, it is important to consider such a correlation when evaluating LED lights.

To date, few researchers have studied the effects of different LCUs as an alternative to resin restorations' compromised bonding[14] or increased microleakage[15] immediately after bleaching. Currently, no data is available on the effect of different polymerization times of LED light sources used for curing the resin material on their bonding strength to an enamel surface immediately after bleaching. Therefore, the current study determined the effect of prolonged polymerization time of a resin composite (Filtek Z250, 3M ESPE, St Paul, MN, USA) using an LED light-curing unit (third generation) on the resin-enamel shear bond strength immediately after bleaching with different bleaching agents (10% CP and 38% HP). Thus, the null hypotheses tested in the current study were: a) there is no difference in resin-enamel bonding strength with increasing the curing time with and without bleaching; b) no changes in bonding efficacy can be seen when bonding is performed after 24 hours of bleaching either with 10% CP or with 38% HP and c) there is no difference in resin-enamel bonding strengths after bleaching with 38% HP when bonding is performed immediately after bleaching.

METHODS AND MATERIALS

Twenty-eight caries-free permanent human molars were collected and stored in a solution of 0.05% chloramine for no longer than one month after extraction. The teeth were cleaned of gross debris and placed in deionized water for 24 hours before beginning the experiment.

The roots of the teeth were removed just below the cemento-enamel junction using a diamond saw (Isomet, Buehler Ltd, Lake Bluff, IL, USA). A total of 56 buccal or lingual surfaces were randomly divided into four equal groups of 14: one control and three bleaching. Each surface was placed inside a PVC matrix, with the intended surface facing upward at the same level as the upper rim of the matrix. Acrylic resin was poured around the specimens, with no resin contaminating the selected enamel surface. Flat enamel bonding sites were prepared by wet grinding with 600-grit silicon carbide paper.

Bleaching Procedure

The first group (CP) was bleached with Opalescence PF bleaching gel (Ultradent Products Inc, South Jordan, UT, USA), a commercially available home bleaching system containing 10% CP. The bleaching gel was applied onto the enamel surface for six hours a day for 14 consecutive days. During bleaching, the specimens were kept in 100% relative humidity at 37°C. After daily bleaching, the specimens were thoroughly rinsed in running water for 10 seconds and stored in deionized water in 100% relative humidity at 37°C for the remainder of the day. After the bleaching period, the specimens were stored in deionized water for 24 hours at 37°C before bonding.

The two other groups (HP) were bleached using a 38% hydrogen peroxide in-office bleaching system (Opalescence Boost, Ultradent Products Inc), following the manufacturer's instructions. The bleaching gel was applied on the enamel surfaces in an approximate 0.5–1 mm layer. A total 30 minutes of bleaching was carried out in two applications of 15 minutes each of the bleaching agent. Upon completion of the bleaching procedure, the specimens were thoroughly rinsed with an air/water spray and air-dried. The specimens were divided into two subgroups: HPA was bonded within one hour, while HPB was stored in deionized water in 100% relative humidity at 37°C for 24 hours before the bonding procedure.

The control group was kept in deionized water (37°C) and renewed daily for two weeks before bonding.

Bonding Procedure

Coltolux LED light-curing unit (Coltene/Whaledent Inc, Mahwah, NJ, USA), with a light intensity of 500 mW/cm^2, was used for light-curing. The cordless LED unit was positioned as close as possible to the specimen during light-curing, and was returned to its battery charger after each specimen was polymerized.

The bonding procedure was performed within one hour after bleaching for HPA and after 24 hours for CP and HPB. The specimens of the four groups (C, CP, HPA and HPB) were further subdivided into two subgroups of seven samples each. Immediately before bonding, all the groups were thoroughly brushed under running water for 30 seconds with a soft toothbrush. The specimens were then etched with 35% phosphoric acid gel (Ultra-Etch, Ultradent Products, Inc) for 15 seconds, rinsed for 10 seconds and gently air-dried. Adper Single Bond 2 adhesive system (3M ESPE) was applied in two consecutive coats, using a small brush, dried with a gentle stream of air and photopolymerized for 10 seconds. To build up the restoration, a hybrid resin composite, Filtek Z250, A3 shade (3M ESPE), was inserted into a 2-mm diameter and 1.8-mm high plastic tube in only one increment. Photopolymerization was performed with the LED unit for two different times as follows: C1, CP1, HPA1 and HPB1 were cured for 20 seconds, while C2, CP2, HPA2 and HPB2 were cured for 40 seconds.

Measurement of Shear Bond Strength

After the composite cylinders were prepared, the specimens were stored in deionized water (37°C) for 24 hours. The specimens were tested in the shear mode using a universal testing machine (Type 8841, Instron Corp, Canton, MA, USA). The embedded enamel specimens were placed in a jig, such that the enamel surface was flush with the edge of the jig, a thin stainless steel wire loop (0.35 mm diameter) was placed around the resin composite cylinder at the enamel-composite interface and a load was applied at a crosshead speed of 1.0 mm/minute until bond failure occurred. The cross-sectional area at the site of fracture was measured to the nearest 0.01 mm with a digital caliper (Mahr 16ES, Carl Mahr, Esslinger, Germany). Shear bond strength values in MPa were calculated from the peak load at failure divided by the specimen surface area.

The results were analyzed using the SPSS program (SPSS 13.0 for windows, SPSS Inc, Chicago, IL, USA). One-way analysis of variance and the post-hoc test were used to obtain the means and standard deviations for all the groups and to compare the means between and within the subgroups at the 5% significance level. Two-way ANOVA was carried out to assess the possible effects of the two factors (treatment x curing time) and their interaction for each bleaching system compared with the control group.

Failure Mode Analysis

After the shear strength tests, the type of bond failure on the enamel surface was observed with a stereomicroscope at 20× magnification. The types of bond failure were classified as: adhesive, if more than 75% appeared to be clean enamel; cohesive in enamel, if a portion of the tooth was removed in the debonded material; cohesive in resin, if more than 75% of the enamel surface was covered with remnants of resin composite and mixed, if between 25% and 75% of the failure was both adhesive and cohesive.

Scanning Electron Microscopy (SEM)

One representative specimen from each subgroup was processed for SEM observation (JEOL USA JSM, 6400, JEOL Ltd, Tokyo, Japan). Each specimen was cross-sectioned and polished on 600 grit silicon carbide papers. The sections were etched for 30 seconds with 10% phosphoric acid, rinsed thoroughly with deionized water, then left to desiccate overnight at room temperature. The specimens were sputter-coated with gold, then the cross-sectioned surfaces were exposed for examination by SEM at magnifications of 2000x using 20 kV accelerating voltage.

RESULTS

Table 1 presents the mean, standard deviation and minimum/maximum values of the shear bond strengths for all the groups. The one-way ANOVA and Tukey's test revealed that there were significant differences within the subgroups of both the C and CP groups ($p<0.05$) but not within the subgroups of HPA and HPB ($p>0.05$). Significant differences were seen between C2 and CP1, HPB1, HPA1 and HPA2 ($p<0.05$), while no significant differences were seen between C2 and either CP2 or HPB2 ($p>0.05$).

The highest bond strength values were seen when the curing time was increased for C2, HPB2 and CP2 (19.93, 18.85 and 16.11 MPa, respectively). On the other hand, the lowest bond strength values were seen

Table 1: *Mean, Standard Deviation (SD), Minimum (Min) and Maximum (Max) Values of Shear Bond Strength in MPA for All Groups*

Group	Mean *	SD	Min	Max
C1	12.38 **ab**	2.82	8.28	15.88
C2	19.93 **acdef**	4.51	17.02	29.24
CP1	8.04 **cg**	3.18	3.17	12.12
CP2	16.11 **g**	5.26	7.10	22.89
HPA1	7.96 **dhi**	1.72	5.12	10.40
HPA2	9.66 **ekj**	1.34	7.65	11.54
HPB1	14.87 **fhk**	2.56	9.44	17.52
HPB2	18.85 **bij**	4.26	12.01	25.18

**Values with same letter are significantly different at* $p<0.05$*. The control subgroups were compared with the subgroups of each bleaching system individually.*

Table 2: *The Modes of Bond Failure for All Groups*

Group	A	CR	CE	M
C1	0/7	2/7	1/7	4/7
C2	0/7	1/7	2/7	4/7
CP1	1/7	2/7	0/7	4/7
CP2	1/7	2/7	0/7	4/7
HPA1	3/7	1/7	0/7	3/7
HPA2	2/7	1/7	0/7	4/7
HPB1	2/7	1/7	0/7	4/7
HPB2	2/7	1/7	0/7	4/7

Adhesive (A), if more than 75%, appeared to be clean enamel; Cohesive in resin (CR), if more than 75%, covered with remnants of resin composite; Cohesive in enamel (CE), if a portion of the tooth was removed with the material and mixed failure; (M) if between 25% and 75% of the failure, was both adhesive and cohesive.

for HPA1, HPA2 and CP1 (7.96, 9.66 and 8.04 MPa, respectively).

Two-way ANOVA showed no significant interaction between the two factors (treatment x curing time) for CP and HPB ($p>0.05$). However, a significant effect of the curing time factor was recorded for all the groups ($p=0.000$).

Table 2 shows the modes of bond failure for all the groups. Both the control and bleached groups showed a predominant mode of mixed failure. Some modes of cohesive-in-resin failures were also seen within all groups. Adhesive failures were recorded more within the bleached groups, particularly those bonded within one hour. There were a few cohesive-in-enamel failures only within the control groups.

SEM microphotographs of the specimens are represented in Figures 1-4. The resin tags, which can be clearly seen penetrating the enamel prisms, were more defined, thick and dense in the control as well as in the bleached specimens when bonding for both bleaching systems was delayed for 24 hours (Figures 1a, 1b, 2a, 2b, 4a and 4b), while shorter, less defined resin tags appeared in the bleached specimens when bonding was performed immediately after bleaching with 38% HP (Figures 3a and 3b).

DISCUSSION

QTH LCUs have been used to polymerize resin composites for many years. Recently, alternative curing units, such as LED and plasma arc (PAC) curing units, have been introduced into the market.[16] These new technologies offer several advantages over QTH units, one of which is reducing curing time, hence, saving chairside time.[17-18] LED LCUs have also been shown to have inherent advantages, such as a constant power output over the lifetime of the diodes, plus, they have great potential to achieve a clinically consistent quality of composite cure.[19] However, different factors have been identified to control the light curing of a resin-based composite: the composition and shade of the composite, the wavelength of the curing unit, the bandwidth, the distance of the curing light from the composite, the light intensity of the unit and curing time.[20]

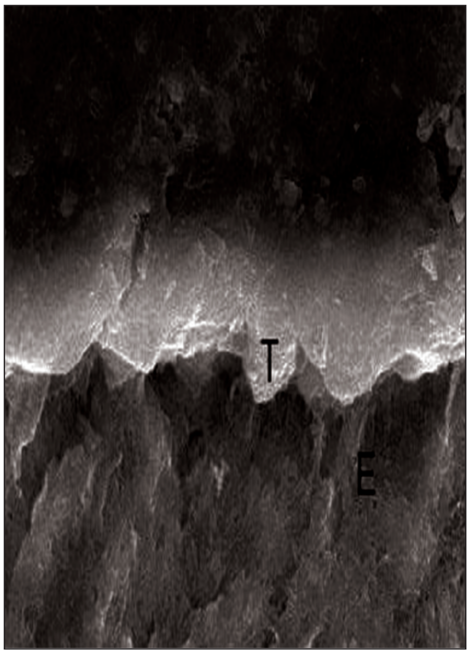

Figure 1a. *Resin composite (C) was cured for 20 seconds when bonded to unbleached enamel. Well-defined resin tags (T) into enamel prisms (E) can be seen in the specimen (2000x).*

Figure 1b. *Resin composite (C) was cured for 40 seconds when bonded to unbleached enamel. Well-defined resin tags (T) into enamel prisms (E) can be seen in the specimen (2000x).*

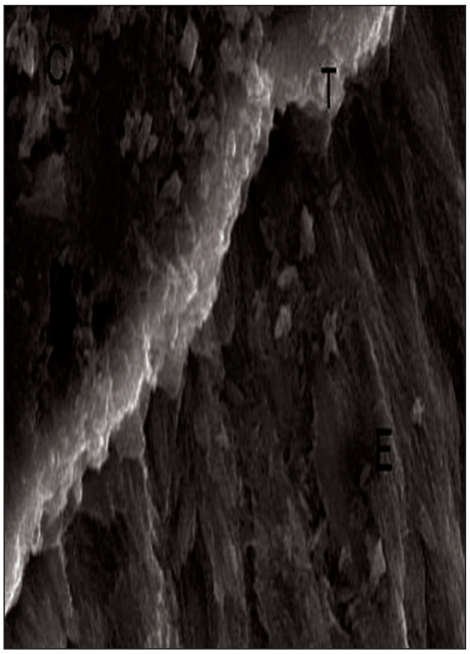

Figure 2a. *CR (C) was cured for 20 seconds when bonded after 24 hours to enamel bleached with 10% CP. Well-defined resin tags (T) into enamel primes (E) can be seen in the bleached specimen (2000x).*

Figure 2b. *CR (C) was cured for 40 seconds when bonded after 24 hours to enamel bleached with 10% CP. Well-defined and long resin tags (T) can be seen in enamel primes (E) in the specimen (2000x).*

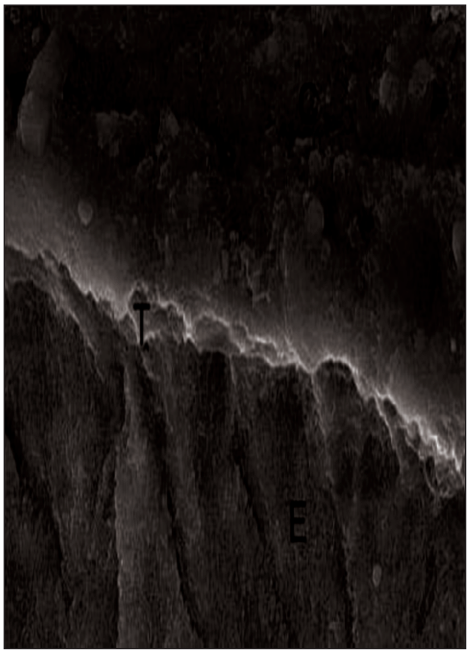

Figure 3a. *Resin composite (C) was cured for 20 seconds when bonded within one hour to enamel bleached with 38% HP. Less defined and short resin tags (T) into enamel prisms (E) can be seen in the specimen (2000x).*

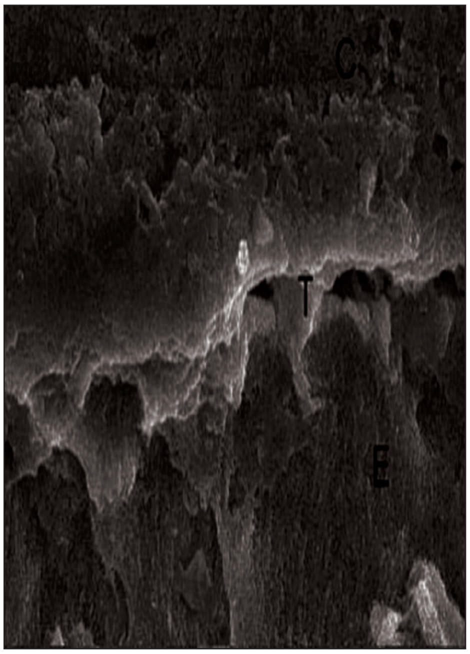

Figure 3b. *Resin composite (C) was cured for 40 seconds when bonded within one hour to enamel bleached with 38% HP. Less defined resin tags (T) into enamel prisms (E) can be seen in the specimen (2000x).*

According to the results of the current study, increasing the curing time to 40 seconds for curing a 2-mm layer of a resin composite using an LED unit, produced significant differences in SBS for each of the control, CP and HPB groups. Thus, the first hypothesis provided by the authors of the current study should be rejected for the control and for those bleaching groups that were bonded after 24 hours and accepted for those bleached and bonded immediately within one hour. Previous studies have concluded that the length of light application of LED units is significantly related to the shear bond strength, and that longer curing time results in a higher bond strength.[21-22] Shear bond strength can be increased by increasing light-curing times in a curvilinear fashion.[23] According to some authors,[24-25] the density of irradiated energy (intensity vs time) determines the degree of polymerization of the material. Adequate polymerization is a crucial factor in obtaining optimal physical properties and the clinical performance of resin composites. Lindberg and others[26] demonstrated a linear relationship between the light intensity of LED lamps and curing depth. Low light intensity can decrease the conversion degree of a resin material;[27] this problem may be solved by increasing the time of photoactivation.[28] Besides, lower intensity of light and more exposure time could improve the marginal integrity of the restorations without decreasing the physical properties.[25] A fixed amount of blue light energy, rather than high light power density output, can result in optimizing the performance of dental composites.[28] Therefore, polymerization time can be reduced to 20 seconds for those LED units of high output levels, such as that of the latest generations with light intensities between 1,500-2,000 mW/cm^2.[29] Thus, it is wise to check the light intensity and irradiation time for LED units used in the clinic, since it has been shown that LED units

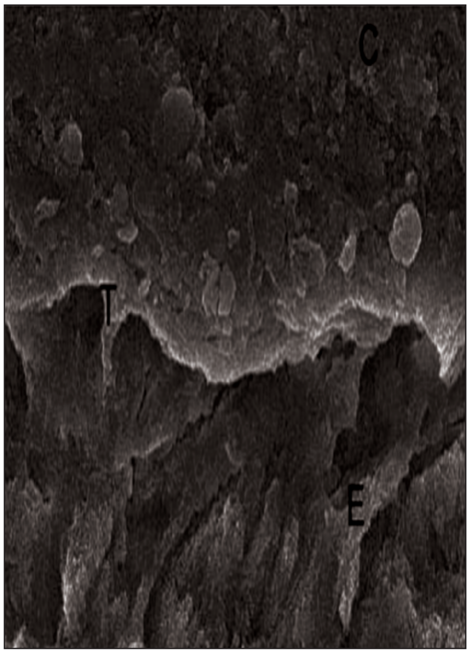

Figure 4a. *Resin composite (C) was cured for 20 seconds when bonded after 24 hours to enamel bleached with 38% HP. Well defined resin tags (T) into enamel prisms (E) can be seen in the specimen (2000x).*

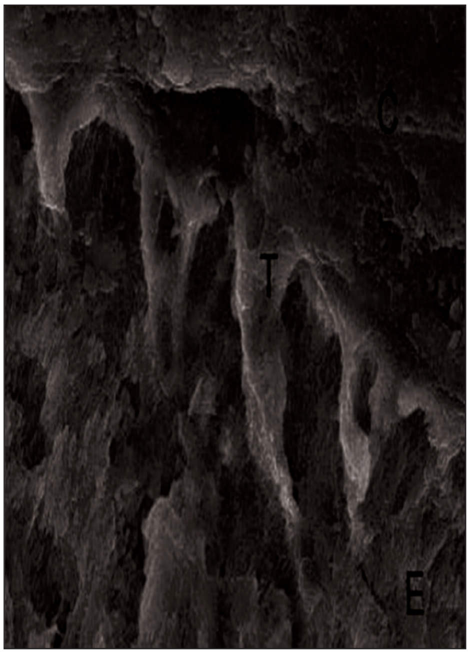

Figure 4b. *Resin composite (C) was cured for 40 seconds when bonded after 24 hours to enamel bleached with 38% HP. Well defined resin tags (T) into enamel prisms (E) can be seen in the specimen (2000x).*

require longer irradiation times than those recommended by their respective manufacturers.[30]

Based on studies in the literature, a reduction in resin-enamel bonding strength after bleaching has claimed to be mostly related to polymerization inhibition due to the presence of residual oxygen from bleaching gels in tooth substrates. Several attempts have been made to overcome such effects, yet delaying the bonding procedure is still the most conservative way to regain resin-enamel bonding strength. However, there seems to be no consensus on the delaying time of bonding procedures after bleaching. The results of the current study showed that, for both bleaching systems, no significant differences were found between the bonding strength values of the control groups and those bleaching groups bonded after 24 hours. This result requires acceptance of the second null hypothesis. Similar results using 10% CP have been reported in previous studies.[14,31] However, a significant difference has been recorded between the values of SBS of the control groups and those bonded within one hour after bleaching with 38% HP. Such results suggest rejection of the third null hypothesis. This result is in accordance with the results reported by Nour El-din and others[4] using 38% HP bleaching agent. The insignificancy between the SBS of the control and bleached groups bonded after 24 hours has been attributed to two factors: brushing the specimens with a soft toothbrush before bonding and the use of artificial saliva as a storing solution. Brushing the bleached enamel surface may enhance elimination of the surface-precipitate formed on the tooth surface after bleaching[32] or for the removal of partially-etched superficial bleached enamel.[33] The use of artificial saliva *in vitro* may simulate the natural saliva function, rendering the detrimental effect of bleaching as being less evident.[34] In the current study, brushing was done with a soft brush before bonding; however, the specimens were stored in deionized water during the study period. Several studies assumed that the use of artificial saliva in laboratory studies and saliva in clinical situations can assist in regaining enamel bonding efficacy after bleaching by producing enamel remineralization. Other studies reported that the *in vitro* immersion of specimens in artificial saliva, distilled water or even saline has been shown to produce a complete reversal of the reduced resin bonding by removing the residual peroxide.[3,10,14] It has been suggested that, during the post-bleaching stage before bonding, elimination of residual peroxide can be achieved by leaching in water in *in vitro* studies or saliva in clinical conditions.[35] The results of the current study support the results of later studies, since resin-enamel bonding strength was regained after 24 hours of immersion of the bleached samples in deionized water.

In addition, the adhesive system used in the current study, an ethanol/water-based adhesive system (Single Bond), might have made a contribution to the lack of any significant influence between the two groups. It has been reported earlier that such adhesive systems may permit the recovery of enamel bonding capacity by interacting with residual oxygen from bleaching found on the enamel surface.[11,14]

Several researchers have addressed other potential reasons that could be associated with the reduction of resin-enamel bond strength after bleaching. Changes in enamel structure after bleaching have been claimed to produce poor bonding surfaces. Reductions in the enamel microhardness due to the loss of calcium and alterations in the organic substance might be important factors in reducing surface energy values and, therefore, affecting adhesion properties.[36] It is evident from the literature that enamel erosion and demineralization caused by bleaching systems depend on several factors, such as pH, acid concentration, temperature, exposure time and frequency of exposure.[37] It has been reported that enamel demineralization can occur at a pH lower than 5.2 to 5.8, and it is the frequency of use of low-pH solutions, rather than the total time of exposure to them, that may result in a non-proportional increase in enamel erosion.[38] However, previous studies have shown conflicting results with the use of different bleaching systems. The differences in various articles written on this subject cannot be reconciled, because of the lack of standardization in the study protocols and/or the fact that the products used had particularly low pH values.[39] Therefore, and for a better comparison, it is necessary to evaluate the effects of each bleaching system individually or at least with close study protocols.

The in-office bleaching system used in the current study was Opalescence Boost, a 38% hydrogen peroxide power bleaching gel with a neutral pH of 7. It contains 1.1% fluoride and 3% potassium nitrate. Such additives, according to the manufacturer, have claimed to improve microhardness and reduce carries susceptibility and lower sensitivity. Cadenaro and others,[40] in their *in vivo* study using Opalescence Boost, observed no detrimental effect on bleached enamel micromorphology. Goharkhay and others[41] inspected enamel morphology using environmental scanning electron microscopy following laser-activated bleaching with Opalescence Boost. No severe alterations on the enamel surface were detected. Sulieman and others[42] showed that a 35% HP bleaching gel with a pH of 7 for 30 minutes produced no evidence of deleterious effects on human enamel. In addition, no differences in the chemical composition of the enamel surface were found after treatment with a high concentration of HP bleaching agents measured by Raman spectroscopy[43] or by electron spectroscopy.[44] Slight changes were observed by Lee and others[45] in bovine enamel's calcium-phosphate ratios following exposure to 30% HP solution for 120 hours. Zalkind and others[46] showed that a highly acidic solution of 30% HP gave morphological changes in enamel after seven days of continuous exposure. Spalding and others[47] observed minor changes after 35% HP bleaching gel application for 20 minutes followed by 10% CP (12 hours/day for one week) treatments but considered these changes to be within normal variations existing in natural teeth and concluded that the bleaching procedures were safe for enamel.

Da Silva and others[48] evaluated the adequate time required to allow the normal penetration of an adhesive onto the enamel surface after bleaching with 38% HP Opalescence Boost. The restorations were performed immediately and 7, 14 and 30 days after bleaching. Better resin tag penetration of adhesive material into enamel was seen with the delayed groups compared to the specimens restored immediately after bleaching. This has suggested that a time interval of at least seven days should be allowed between enamel bleaching and placement of adhesive bonding agents for the accomplishment of resin composite restorations. However, no attempt was made to compare a 24-hour period of delay to the immediate or control specimens. Thus, it is unclear whether a seven-day period is the minimum amount of time required to establish resin tag penetration into bleached enamel.

On the other hand, the home bleaching agent used in the current study (10% carbamide peroxide, Opalescence PF) contains 0.11% fluoride ion and potassium nitrate with a near-neutral pH of 6.5. Several studies demonstrated that no significant changes can be found in the chemical composition of the enamel surface when using CP bleaching agents.[49-50] Other studies showed that some CP formulations may alter the enamel surface, causing surface dissolution and exposing a porous and eroded surface.[51-52] Carbamide peroxide-containing agents have been reported to affect the mineral content and organic phase of the superficial layer as well as the inner structure of the enamel.[51-53] Such an effect could result in changes in the mechanical properties of enamel, such as fracture toughness, leading to a decrease in bonding strength. Urea, which is a by-product of CP, has been shown to remove enamel proteins and related mineral elements,[54] attacking the core or intra-prismatic area and producing porosities at prism surfaces.[55] However, urea may provide beneficial effects due to the pH rise of the bleaching solution.[56] Glycerin or carbopol, the most common carriers in the carbamide peroxide bleaching formula, may also act as a demineralizing agent.[57] However, carbamide peroxide-based bleaching agents containing fluoride or calcium may impair mineral loss usually promoted by bleaching.[58] This fact can be related to the super saturation of fluoride-containing bleaching gels. Moreover, these ions favor the remineralization or precipitation in intraprismatic structure.[58] Therefore, changes observed after vital bleaching may depend on the composition of the applied bleaching product and its pH-value.[59] It seems that both bleaching agents used in the current study exerted less influence on the surface alteration of tooth substrates. Recent bleaching systems with a neutral pH and additional additives may not have the same effect on the tooth substrates as the old ones.

Several studies have reported that less depth of resin tag penetration in bleached enamel compared to unbleached enamel can be seen using SEM[4] and optical light microscopy.[48] Decreased bond strength of the resin composite has been reported to be vastly related to the quality of resin tags.[2] These results concur with the results of the current study, wherein both the quantity and quality of the resin tags were seen to be better in both the control and bleached specimens (bonded after 24 hours) with higher bonding strength values.

In the current study, the modes of bond failure were predominantly mixed for all groups. Cohesive in resin modes were also seen but to a lower extent for most of the subgroups. The presence of a high percentage of mixed failures indicated an adequate interaction of the adhesive system with the substrates.[60] More incidences of adhesive failure were seen within the bleached groups, particularly the subgroups bonded within one hour after bleaching. However, it has been reported that no bond strength and failure mode standardization can be observed and there is no correlation between the failure mode and bond strength value.[4]

Further investigations are needed to explore the influence of the curing time of different light intensities of LCUs on resin bonded immediately after bleaching to enamel and dentin.

CONCLUSIONS

Within the limitations of the current study, the authors can conclude:.

1. Prolonging the photopolymerization time of a resin composite, using an LED unit with a light intensity of 500 mW/cm^2, can increase the shear bonding strength of a resin composite to enamel with and without bleaching.
2. A 24-hour period of delayed bonding to bleached enamel, whether with 10% CP or 38% HP, was sufficient to regain SBS comparable to that of the control.
3. Bonding strength of a resin composite was compromised when bonded immediately to enamel bleached with 38% HP

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