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Original Paper

The Effect of Different Light Sources on Microleakage of Bleached Enamel

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This study evaluated the immediate effects of halogen, LED (light-emitting diode), and plasma arc curing units on microleakage of bleached enamel. The buccal and lingual enamel surfaces of experimental groups (n=30) were bleached with 16% carbamide peroxide for a period of 10 days, with a daily contact time of 90 minutes. Box-shaped Class V cavities were also prepared on 60 extracted molar teeth (n=30, control group). For all groups, a composite resin (Grandio) was bonded with one of the two employed adhesive systems, Single Bond 2 or Prime & Bond NT. After restoration, all specimens were thermocycled for 200 cycles between 5°C and 55°C with a dwell time of 60 seconds in each bath, and then exposed to a dye. In the control groups, microleakage was statistically lower than the bleached groups ($p<0.01$). Groups cured with QTH and PAC showed no statistical differences ($p>0.05$). However, groups cured with LED system showed statistically significant differences ($p<0.01$) in microleakage.

Key words: Bleaching, Microleakage, Light curing units

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INTRODUCTION

Bleaching is a less expensive alternative than other esthetic measures[1]. The use of carbamide peroxide (CP) and hydrogen peroxide (HP) agents to bleach vital teeth has become a popular treatment method[2]. The bleaching process involves a constant application of peroxide on stains located within the superficial layers of tooth structure. As bleaching time increases, the peroxide permeates deeper into the enamel and thus produces a lightening effect[1].

When the results obtained from vital bleaching treatment are not esthetically acceptable, immediate composite resin restorations may be indicated after vital bleaching procedure to achieve better esthetic results[3,4]. However, a number of studies have declared low bond strength values of composite resin restorations to enamel when bonding was carried out immediately after bleaching[3,5,6]. In light of this finding, it has been recommended to delay the placement of composite resin restorations for at least 1−3 weeks after bleaching[3,7-9].

The reduction in bond strength is associated with changes in the adhesive characteristics of the bonding resin and in the resin quality. Poor adhesion between tooth and restorative material predisposes the interface to gap formation, which then leads to microleakage. Consequently, microleakage leads to a host of serious clinical problems such as secondary caries, marginal discoloration, pulpal inflammation, and hypersensitivity[10-12]. To date, several methods have been proposed to avoid the aforementioned clinical problems due to immediate placement of composite restorations and which lead to decrease in bond strength[2]: removal of superficial layer of enamel[13], surface treatment[3,5], and use of adhesives containing organic solvents[1].

Similarly, the presence of residual peroxide at or near the enamel surface is also a factor that adversely affects bond strength[8]. Residual oxygen from the bleaching agent can interfere with the polymerization of resins and thus affect the bond strength to enamel. To preclude the detrimental effect thereof, it is therefore important that residual oxygen be eliminated from the enamel surface before the composite bonding procedure is carried out.

On factors that affect the clinical performance of composite restorations, polymerization shrinkage is still a critical limitation of dental composites. No dentin bonding agents are yet able to completely counteract the formation of contraction gaps between the cavity walls and composite restorations. To improve the depth of cure and mechanical properties, it is typically recommended to polymerize composites with high-intensity light sources[14].

Nearly all of the contraction stress is developed within seconds after the irradiation of light-activated resins[10]. To date, several studies have been undertaken to evaluate the effect of light sources on the microleakage[15] or bonding strength[16] of composite resin restorations. A light source can be an alternative to delayed bonding, especially when a restoration has to be completed immediately after bleaching. However, currently, no data is available on the effect of light sources on microleakage after bleaching — and hence no consensus on the immediate effect of LCUs (light curing units) on bleached enamel surfaces. Nonetheless, it is noteworthy that composite materials undergo measurable changes after light exposure[17].

A wide range of LCUs is currently available. Each has its own advantages and disadvantages with respect to the properties of the final restoration and the long-term success of the restored tooth[18]. Curing lights differ in intensity output, ranging from 200 to 1000 mW/cm^2 or more[19]. Quartz-tungsten-halogen (QTH) LCUs have been used to polymerize composite resins for many years. The main drawback of QTH LCUs is a decrease in irradiance over time due to the aging of lamp and filter. This may result in a low degree of conversion and a shallow depth of cure, thereby reducing the quality of the final restoration[18,20]. Recently, alternative curing units such as plasma arc (PAC) and light-emitting diode (LED) curing units have been introduced into the market[20]. These new technologies offer advantages such as absence of heat generation during curing, reduced curing time and hence saving chairside time[21-23].

With the available range of LCUs, it is important to investigate if these LCUs could reduce — or perhaps eliminate — the delay period of new restoration placement after bleaching. This goal was suggested to be achieved through a polymerization process that ensures superior qualities for the final restoration of recently bleached teeth.

Therefore, the purpose of this study was to evaluate the effects of three different light sources on the microleakage of composite resins immediately bonded to bleached enamel with two adhesive systems.

MATERIALS AND METHODS

Sixty extracted, caries-free human molar teeth were selected for this study. Immediately after extraction, the teeth were cleaned using scalers to remove soft tissue remnants. The teeth were stored in saline solution for at least eight weeks.

Bleaching procedure

In most published studies, home bleaching products (10−16% carbamide peroxide) were generally used within a 2−4 week bleaching simulation period with application intervals of 4−8 hours per day[7]. In this study, Polanight (16% Carbamide Peroxide Gel, Lot No. 040931, SDI, Australia) was used for 90 minutes per day according to manufacturer's instructions. For the experimental groups (*i.e.*, groups in which bleaching was performed), the buccal and lingual enamel surfaces were placed in individual soft, plastic trays filled with the bleaching gel for a period of 10 days. Daily contact time was 90 minutes. After completion of the daily bleaching procedure, excess gel was removed from the specimens and the latter rinsed in running water, using a soft toothbrush for 10 seconds. For the remaining hours of the day, specimens were stored in distilled water at 37°C.

Cavity preparation

Box-shaped Class V cavities (one on the buccal surface and another one on the lingual surface of each tooth) were prepared with a cylindrical diamond bur (806315111534010, Lot No. 061010, 3097G) in an air/water-cooled high-speed turbine. Occlusal margins of the cavities were located in the enamel and the gingival margins at the cementoenamel junction. All the prepared tooth specimens were etched with 37% phosphoric acid etching gel (Ivoclar Vivadent, Lot No. H36568) for 20 seconds. The

Table 1 Manufacturers and contents of the adhesive systems used in this study

Adhesive System	Contents	Manufacturer	Lot number
Prime & Bond NT (PBNT)	*Bonding agent* Acetone PENTA, UDMA, Resin R5-62-1, T-resin, Dresin	Dentsply, Detrey/ Caulk Milford DE	509002446
Single Bond 2 (SB2)	*Bondisng agent* Bis-GMA, HEMA, polyalkenoic acid copolymer, ethanol, water, photoiniator	3M ESPE Adper, Dental Products, St.Paul, MN	55144Lot: 4BF

PENTA: Dipentaerythritol penta acrylate monophosphate
UDMA: 1, 6-bis (methacryloxy-2-ethoxycarb-onylamino)-2,4,4-trimethylhexane
Bis-GMA: 2, 2-Bis[p-(2'-hydroxy-3'-methacryloxypropoxy)-phenylene]propane
HEMA: 2-hydroxyethyl methacrylate

Table 2 Light curing units used in the study and their outputs

Light curing unit	Lowest light intensity	Curing mode
QTH (Hilux, Benlioğlu Dental, Ankara, Turkey)	400mW/cm^2	Continuous energy output for 20s
LED (SmartLite PS, Dentsply, Germany)	700mW/cm^2	Continuous energy output for 20s
PAC (Plamaster, Monitex Industrial Co. Ltd, Korea)	More than 1800mw/cm^2	Continuous energy output for 6s

＊Intensity of LCUs were measured using a radiometer (Demetron/Kerr Corp, USA)
QTH: Quartz halogen, LED; Light emitting diode, PAC: Plasma arc

cavities were then rinsed for 15 seconds under water. Cavity preparation was approximately 2 mm in height, 3 mm in the mesio-distal direction, and 1 mm in depth. All the standard cavities were prepared by only one operator. Two adhesive systems, Prime & Bond NT (PBNT, acetone content) and Single Bond 2 (SB2, ethanol content), were used for the bonding procedure in the cavities. Properties of the adhesive systems are given in Table 1.

For all the groups, the same nano-hybrid composite resin (Grandio, Lot No. 440100, Voco, Cuxhaven, Germany) was used. Two layers of the composite were added to each cavity. Each layer was then cured with one of the following light curing units: LED (SmartLite PS, Dentsply, Germany), QTH (Hilux, Benlioğlu Dental, Ankara, Turkey), and PAC (Plasmaster, Monitex Industrial Co. Ltd., Korea) (Table 2). Finishing and polishing, using Identoflex Composite Polishers (Lot No. 80600824, Kerr, USA,), was performed immediately after curing.

The specimens were randomly assigned into the following 12 groups (n=10) according to bleaching treatment, light source, and adhesive system:

G1: Bleaching + QTH + PBNT
G2: Bleaching + QTH + SB2
G3: QTH + PBNT (Control)
G4: QTH + SB2 (Control)
G5: Bleaching + LED + PBNT
G6: Bleaching + LED + SB2
G7: LED + PBNT (Control)
G8: LED + SB2 (Control)
G9: Bleaching + PAC + PBNT
G10: Bleaching + PAC + SB2
G11: PAC + PBNT (Control)
G12: PAC + SB2 (Control)

Thermocycling and microleakage test

After restoration, all specimens were thermocycled for 200 cycles between 5°C and 55°C with a dwell time of 60 seconds in each bath[24]. Following thermocycling, the root apices were occluded with wax and the teeth coated with two layers of nail varnish up to 1 mm from the restoration margins. Specimens were immersed in 0.5% basic fuchsin solution for 24 hours at room temperature. Following removal from the solution, the teeth were rinsed under tap water and sectioned buccolingually through the center of the restoration with a diamond disc (Lot No. R01-1535, Finzler, Schrock & Kimmel GmbH, 56130 Bad Ems, Germany) under water cooling.

A mean microleakage value was derived from each half of the specimen. Microleakage was evaluated using the following standardized scoring system, which was similar to that used by Demarco *et al.*[25]:

0 = No leakage
1 = Leakage at the gingival wall
2 = Leakage at the cavity base

Enamel and dentin margins were scored separately. Both halves of each sectioned tooth were evaluated under a stereomicroscope (Olympus BH2 BHT Binocular Biological Microscope, Japan) at ×20 magnification.

Statistical analysis

Data were subjected to statistical analysis using Kruskal−Wallis and Mann−Whitney U tests.

RESULTS

Microleakage scores for occlusal and gingival margins are presented in Table 3. Microleakage at the occlusal margin showed no significant differences among all treatment groups, and all scores were either 0 or 1. Group 11 (PAC + PBNT) did not exhibit any microleakage at the occlusal margin. Among the light curing units, there were no significant differences ($p > 0.05$) in microleakage score at the occlusal margin.

There was greater microleakage at the gingival margin than the occlusal margin, and this difference was statistically significant ($p<0.01$) (Table 4). No statistically significant differences ($p>0.05$) were found between QTH and PAC. As for LED, it showed statistically lower microleakage scores ($p<0.01$) at the gingival margin.

Table 3 Treatment groups and their microleakage scores (n=10)

Groups(n=10)	Microleakage Score Occlusal Margin 0	Occlusal Margin 1	Occlusal Margin 2	Gingival Margin 0	Gingival Margin 1	Gingival Margin 2
1 Bleaching + QTH + PBNT	9	1		6	3	1
2 Bleaching + QTH + SB2	9	1		7	3	
3 QTH + PBNT (Control)	8	2		8	2	
4 QTH + SB2 (Control)	9	1		7	3	
5 Bleaching + LED + PBMT	8	2		3	4	3
6 Bleaching + LED + SB2	6	4		3	6	1
7 LED + PBNT (Control)	9	1		8	2	
8 LED + SB2 (Control)	9	1		3	4	3
9 Bleaching + PAC + PBNT	7	3		4	3	3
10 Bleaching + PAC + SB2	7	3		3	6	1
11 PAC + PBNT (Control)	10			8	2	
12 PAC + SB2 (Control)	9	1		9	1	

Table 4 Mean microleakage scores at occlusal and gingival margins

Margin	N	Mean Rank
Occlusal margin	120	104,00
Gingival margin	120	137,00
Total	240	

Table 5 Mean microleakage scores of bleached and control groups

Treatment	N	Mean Rank
Bleached	120	133.26
Control	120	107.74
Total	240	

Table 6 Mean microleakage scores between light curing units

Light curing unit	N	Mean Rank
QTH	80	109.67
LED	80	132.28
PAC	80	119.55
Total	240	

Table 7 Mean microleakage scores between adhesive systems

Adhesive system	N	Mean Rank
PBNT	120	117.47
SB2	120	123.53
Total	240	

In the control groups, microleakage was statistically lower than the bleached groups ($p<0.01$) (Table 5). Kruskal−Wallis test showed no statistically significant differences in groups cured with QTH and PAC ($p>0.05$). However, statistically significant differences in microleakage were observed in groups cured with the LED system ($p<0.01$) (Table 6).

Between the adhesive systems of PBNT and SB2, there were no statistically significant differences in microleakage score ($p>0.05$) (Table 7).

DISCUSSION

A typical bleaching agent contains CP or HP as its active component26). In the bleaching process, CP reacts with water to release HP6). HP is a strong oxidizing agent with a low molecular weight. Oxygen atoms are released when hydrogen peroxide is decomposed27).

Peroxides decompose into free radicals, which in turn break down large pigmented molecules into smaller, less pigmented ones6).

The success of a bleaching procedure hinges on the ability of the whitening agents to penetrate enamel and dentin28). At the same time, studies have reported on significant decreases in the microhardness values of both enamel and dentin after exposure to different concentrations of carbamide and hydrogen peroxide29,30). Tooth enamel is the densest tissue in the human body and has a very low permeability. This means that permeation of HP through enamel will be slow. Tooth enamel is also a low reactive tissue. This means that bleaching effect can be achieved only when the bleaching agent is in contact with the enamel for a sufficient period of time. In other words, the release of oxygen atoms should occur constantly and over a long enough time for bleaching to be effective27). On HP penetration, it has been shown that 14% HP rendered a higher pulpal penetration than 6.5% HP[28].

When a cavity is designed at the buccal surface, the occlusal margin of the cavity is located in the enamel and the gingival margin at the cementoenamel junction. However, enamel is thick at the occlusal margin but very thin at the gingival margin. Therefore, the bleaching agent will also affect dentin. On this ground, we also evaluated the microleakage scores at the gingival margin. In this study, 16% CP was used for 90 minutes per day. Despite a seemingly short time; CP penetration occurred because bleached groups showed statistically higher microleakage values than the control groups.

The lower bond strength obtained after bleaching the enamel could be due to residual oxygen from the bleaching agent[2,9,31]. Although the underlying mechanisms remain to be fully elucidated, the hypothesis is that as the oxidizing agent HP permeates through the enamel and dentin, the highly pigmented carbon ring compounds are opened and converted into chains[4]. However, the adverse effect of hydrogen peroxide on resin adhesion is reversible and short-lived[8].

A high concentration of oxygen remains in the pores of the enamel surface after bleaching. Since polymerization of current bonding agents is known to be inhibited by oxygen, the extent of polymerization of the resin tags in enamel was thus lowered. This then resulted in decreased bond strength of teeth bonded immediately after bleaching[2]. in a study by Türkün and Kaya[3], SEM examination revealed a porous and granular appearance of the adhesive resin in specimens that were bonded immediately after bleaching. It might be due to gaseous bubbling, a result of oxidizing reactions due to the entrapment of peroxide in the subsurface layer of enamel. The exact depth of oxygen-rich layer of enamel is not known. However, it must be greater otherwise; the acid etching procedure would have removed this layer[2].

In this study, depth of the cavity preparation was 1 mm. The hypothesis was that such a preparation would have the oxygen-rich layer removed, and thus no differences would be observed between the bleached and control groups. However, the bleached groups showed statistically higher microleakage scores than the control groups. Therefore, the procedure of removing 1 mm of enamel, with a view to eliminating the immediate effect of bleaching, did not augur well as a remedy to prevent microleakage. It is also noteworthy that low bond strength after bleaching might not be only due to released oxygen, but might also stem from changes in proteins and mineral content of the most superficial layers of enamel[32].

At the restoration/tooth interface in an oral environment, the properties of restorative resins play an important role in determining the marginal gap dimensions and hence microleakage. Indeed, the properties of a restorative resin will directly influence its polymerization shrinkage during curing, as well as differences in thermal expansion coefficients between tooth and restoration[10]. The effect of contraction stress on bond strength depends not only on the type of resin composite[33], but also on the type of dentin adhesive[34] and solvent type[24].

According to Sung *et al.*[1], alcohol-based adhesive systems permit the recovery of enamel bonding capacity. Alcohol present in a bonding agent could interact with residual oxygen from the bleaching agent found on the enamel surface[16]. Yazici *et al.*[24] reported that dentin adhesives containing acetone (PBNT) as a solvent showed less microleakage than the ethanol-containing bonding system. Moreover, it was reported that dentin adhesives that contained acetone performed best when resin was placed on conditioned tooth surfaces[35]. However, in this study, no statistically significant differences in terms of microleakage were observed for both acetone (PBNT) and ethanol (SB2) adhesive systems. A probable explanation for this was that the solvents of the adhesives (PBNT and SB2) were not able to minimize the inhibitory effects of the recently completed bleaching process.

Microleakage may vary depending on the design of the cavity preparation[25,36]. The ratio of the cavity volume to the area of the cavity walls as well as the volume of the restoration have a significant influence on marginal gap dimensions[10]. In nonretentive V-shaped preparations, the volume of composite resin and polymerization shrinkage are probably lower[36]. However, contrary to expectations, Kaplan *et al.*[37] reported that a retentive cavity preparation restricted the movement of composite resin restorative material such that retentive cavity preparations exhibited less microleakage than nonretentive cavity preparations. In view of this result[37], retentive box-shaped cavities were prepared in this study. However, microleakage was not eliminated.

With enamel, the thicker cavity wall and the more organized prism structure will allow adequate bonding, hence rendering restorations with better results[38]. Further, with the introduction of acid etching technique, the problem of microleakage at margins finished on enamel has been largely resolved[39]. Indeed, Civelek *et al.*[40] reported that no statistically significant differences in dye penetration and microleakage results at the enamel margin were observed among the different restorative materials employed. On the other hand, microleakage at dentin could not be efficiently eliminated with any adhesive restorative material. Bachmann *et al.*[41] stated that, in contrast to enamel, dentin has a more complex structure that allows successful bonding to dentin only if optimal interlocking with an adhesive system to dentin can be achieved. Their study yielded higher microleakage values at the cementum margin for all material groups and techniques. In this study, Mann−Whitney U test revealed significant differences in microleakage between the occlusal and cervical margins — with higher microleakage values at the cervical margin. As for the influence of LCUs, no statistically significant differences in microleakage were observed among the LCUs used at the occlusal margin located in enamel. However, at the gingival margin, QTH and PAC showed statistically less microleakage than LED.

In the present study, one of the objectives was to investigate if a light source could reverse the adverse effect of bleaching on bond strength. At the present moment, there is a paucity of information about the effect of light sources on microleakage after vital bleaching. Therefore, it is not possible to compare the results obtained in the current study with any published studies. Nonetheless, adhesion is related to microleakage, which means that lower bond strength values after tooth bleaching may promote microleakage around restorations[42)]. On this ground, the microleakage results obtained in this study were compared against those obtained by Loretto *et al.*[16)], who evaluated the bond strength of bleached enamel. They concluded that light source type did not affect immediate enamel bond strength after bleaching with 10% CP.

With a view to improving the immediate depth of cure, polymerization of composites with high intensity light sources is typically recommended[14)]. Nalçacı *et al.*[15)] reported that although microleakage may not be eliminated, differences in light source type could affect the performance of composite resins. However, some authors reported that light source type had no significant effect on microleakage[21,43)]. Amaral *et al.*[43)] reported that the restorative material itself might be a more critical factor in adhesion than the curing method. In complete contrast to this suggestion by Amaral *et al.*[43)], Brackett *et al.*[44)] concluded that curing method was a significant factor than the restorative material. The latter study[44)] revealed that the greatest incidence of microleakage in Class V resin-based composite restorations was observed in restorations cured by plasma arc method.

Microleakage is a complex phenomenon. In this study, neither the bonding system nor the LCU could prevent microleakage at the gingival margin as effectively as at the occlusal margin. Moreover, the enamel substrate is vulnerable to bleaching reactions[9)], with the bleaching agents dissolving and increasing the porosity of the enamel surface. Therefore, caution and discretion must be diligently exercised with respect to their recommendation and application in common use[45)].

In this study, differences in microleakage were found between the bleached and unbleached groups whereby the bleached groups showed statistically greater microleakage. As for the influence of light source, Kruskal−Wallis test showed that groups cured with LED system showed higher microleakage values.

CONCLUSION

Within the limitations of this *in vitro* study, it was concluded that neither the light source nor the adhesive system could effectively prevent microleakage for teeth bonded immediately after enamel bleaching. Based on the results of this study, immediate restoration after vital bleaching is not recommended.

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