The Effect of Antioxidant Treatment on the Shear Bond Strength of Different Bonding Systems to Bleached Enamel

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ABSTRACT

BACKGROUND

Nowadays, teeth whitening has become an important procedure in dental practice. According to results of previous studies, the bond strength values of bonded restorations are decreased when the teeth have been whitened with an office or home bleaching technique. The aim of this in-vitro study is to explore the effect of antioxidant implementation on enamel after whitening on the shear bond strength to enamel surface.

METHODS

The buccal enamel surfaces of 100 extracted teeth were divided non randomly into two groups for bonding with Single Bond [Group A] (3M ESPE) or Clearfil SE [Group B] (Kuraray). Each group was then divided into five random subgroups: 1. the negative control group (NC) received no whitening treatment [Group A1 and Group B1]; 2. whitened with 15% carbamide peroxide and that received no antioxidant agents [Group A2 and Group B2]; 3. whitened with 15% carbamide peroxide and implemented 10% sodium ascorbate (SA) [Group A3 and Group B3]; 4. whitened with 35% hydrogen peroxide and that received no antioxidant agents [Group A4 and Group B4]; 5. whitened with 35% hydrogen peroxide and implemented 10% sodium ascorbate [Group A5 and Group B5]. After the restorations were done with a composite (Clearfil ST, Kuraray), they were shear-tested until failure. Two-way analysis of variance (ANOVA) test and Tukey's multiple comparisons test were used to check shear bond strength data at a significance level of p= 0.05.

RESULTS

Shear bond strength values of used bonding systems immediately after bleaching to whitened enamel, were significantly lower than those of non-whitened enamel ($p<0.05$). No statistically significant differences in shear bond strengths were found for two adhesive systems, when the antioxidant implemented groups were compared with the non-whitened group (Control) ($p>0.05$). Thus, the enamel bond strengths of the bonding systems were reversed following sodium ascorbate treatment.

CONCLUSIONS

It was concluded that the antioxidant sodium ascorbate application could fully neutralize the destructive actions of whitening agents on shear bond strength.

KEY WORDS

Enamel, Dental Whitening, Adhesion, Antioxidants.

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BACKGROUND

Nowadays the popularity of teeth whitening in dental practice has increased.[1] Internal and external whitening procedures may be done using 3–35% Hydrogen peroxide solutions and hydrogen peroxide releasing agents like sodium perborate or carbamide peroxide.[2] Generally, in office tooth whitening are made with high concentration of hydrogen peroxide agents (25%-35%) accompanied by heat source and a rubber dam to protect the gingival tissues.[3] Haywood and Heymann[4] applied carbamide peroxide (CP) agent to patient for home whitening. Since that time, many manufacturers have introduced different types of at-home whitening systems using different concentration of CP such 10%, 15% -16%, or 20%- 22% for whitening agent.[5,6]

Patients' increasing interest in whiter teeth requires clinicians to learn more about appropriate whitening solutions and treatment options. Kugel et al.[7] Suggested the consecutive usage of in-office and at-home whitening systems to bleach teeth because the consecutive usage improves the impact of teeth whitening. However, patients are generally interested in other esthetic dental treatments after they have whitened their teeth.[8]

According to results of previous studies the bond strength values of bonded restorations are affected when the teeth have been whitened with the usage of hydrogen peroxide (HP) or carbamide peroxide (CP) when bonding is performed immediately after a whitening treatment.[9-11] Same way, previous studies find out that the bond strength values of bonded restorations is decreased when the teeth have been whitened using hydrogen peroxide (HP) or carbamide peroxide (CP) whitening agents.[10,12-17]

Josey et al. have shown that night-guard vital whitening agents cause a significant disrupt in the surface texture of the whitened enamel.[18] They considered that whitening resulted in deformations of enamel prisms on the enamel surface, similar to etched enamel. Dishman et al.[19], observed that usage of 25% hydrogen peroxide for in-office whitening, causes a reduction in the number of resin tags and recommended that whitening leads polymerization restriction, which could decrease bond strength. Whitening agents caused to the decreased bond strengths of whitened enamel and dentin because of free oxygen radicals, the result of the oxidative process.[20,21] Similarly, Lai et al.[17] recommended that the decrease in bond strength between bonding systems and enamel could be because of the remaining oxygen in the enamel structure after whitening, which affects polymerization of adhesive monomers.

Various methods to prevent clinical problems associated with decreased bond strength after whitening have been proposed, like the taking out of affected superficial layers of the teeth,[22] application the alcohol on whitened enamel surface,[21] and usage of different adhesives including organic solvents.[23, 24]

Turkun et al.[25] Studied on the effects of two in home whitening agent containing 10% carbamide peroxide on the enamel surface. They showed that, these peroxide agents were the reason of the changes in enamel-surface morphology immediately after whitening, and level of this surface modification were attached to the brand of the whitening agent and the application period. However, these changes in enamel-surface could come back to almost normal within 3 months. According to Spyrides et al.[26] three whitening regimens (35% HP, 35% CP, and 10% CP) decreases the bond strengths on dentin when the bonding agent applied on whitened teeth immediately after whitening. Spyrides et al.[26] Van Der Vyver et al.[27] and Cavalli et al.[28] Studied on the bond strength of composites to whitened dentin and they come to a decision that, for reversing the deleterious effect of whitening, bonding procedures should be postponement for minimum 2 weeks after whitening. The time required for bonding procedures after whitening period varies from 24 hours to 2 weeks. Nevertheless, the usage of anti-oxidant agents on whitened enamel before the bonding process has been shown to reverse the deleterious effect. In a study by Lai et al.[29] the antioxidant sodium ascorbate when is applied to the dentin surface of the teeth before bonding has been shown to be reversed the decreasing effect of whitening on the bond strength of composite resin which occurs after whitening procedures. In another study, Lai et al.[17] Found that, sodium ascorbate when employed on enamel surface after whitening and before bonding procedures, could reverse the shear bond strength values to the control level.

The aim of this in-vitro study is to explore the effect of antioxidant implementation on enamel after whitening with CP and HP on the shear bond strength of two different dental adhesives to enamel surface. The null hypothesis tested was that the adhesion of different dental adhesives to enamel would not be affected by the applied antioxidant treatment after whitening with CP or HP.

METHODS

This was a non-randomized controlled in-vitro study performed in Research Laboratory of Selcuk University Faculty of Dentistry. Freshly extracted one hundred, sound, human mandibular incisors were gathered and placed in 0.1% thymol solution. The teeth were cleaned and washed with tap water before the study. Roots were removed from the crowns at the cemento-enamel junction and embedded in standardized 15x18x29 mm polyethylene molds bearing self-curing resin with the buccal surfaces uncovered; after that stored in distilled water at 4°C until needed. Then each batch of hundred teeth were assigned a number and were non randomly divided into 10 groups of 10 teeth each: eight experiment and two control groups. Sample size estimated by statistical power calculator program (Gpower, v. 3.1.9.4, F. Faul, University of Kiel, Germany). Post-hoc power calculation revealed that a power of 0,99 could be obtained with this sample size (Parameters: shear bond strenght (SBS), total sample size 100, number of groups 10, statistics based on F-test, effect size calculated by mean SBS values = 0.8).

Distribution of Teeth

The buccal enamel surfaces of 100 extracted human mandibular incisors were first divided non randomly into two groups for bonding with Single Bond [Group A] (n=50) (3M ESPE) or Clearfil SE [Group B] (n=50) (Kuraray).Then, each group was divided into five nonrandom subgroups; 1. The negative control group (NC) received no whitening treatment [Group A1 and Group B1] (n=10 for each groups); samples in the control group were not whitened but were kept in artificial saliva for 1 week before the bonding

procedure; 2. specimens that were whitened with 15% CP and that received no antioxidant agents [Group A2 and Group B2] (n=10 for each groups); 3. specimens that were whitened with 15% CP and treated with 10% sodium ascorbate (SA) [Group A3 and Group B3] (n=10 for each groups); 4. specimens that were whitened with 35% hydrogen peroxide gel for 30 minutes and that received no antioxidant agents[Group A4 and Group B4] (n=10 for each groups); 5. specimens that were whitened with 35% hydrogen peroxide gel for 30 minutes and treated with 10% sodium ascorbate[Group A5 and Group B5] (n=10 for each groups) (Table 2).

Whitening Procedure

Just before whitening, the enamel surface of the samples was polished with wet 600- grit silicon carbide abrasive paper for 60 seconds to create a flat enamel surface. Then, the surface was polished with a slow-speed handpiece using a brush with a pumice and water, then rinsed again, Afterward, the predetermined procedures for each experimental group were followed. The experimental groups Group A2, Group A3, Group B2, and Group B3 were whitened with at-home whitening gel 15% CP (Opalescence, Ultradent, USA). Whitening agent was applied on the enamel surfaces of the specimens for 8 hours a day, according to the manufacturer's instructions. After that whitening process, samples were washed with water and air-dried for 30 seconds. The whitened samples were kept in 250 ml of artificial saliva for the rest of the day. The procedure was repeated every day for a week.

Group A4, Group A5, Group B4, and Group B5 were whitened with 35% HP. 35% HP at-office whitening gel (Opalescence Extra, Ultradent, USA) was applied to the enamel surfaces of the embedded teeth according to the manufacturer's instructions. The whitening procedures involved 3 applications of 10 minutes each. The whitening gel was light-activated 4 times for 40 seconds each with a photocuring unit (Monitex Blue Lex GT1200, Taipei, Taiwan) for each application. The gel was agitated with a dental brush to remove bubbles in gel after light activations. After the whitening process, the samples were washed with water for 10 minutes to remove residual whitening gel.

Application of Antioxidant

In antioxidant groups (Group B3, Group A3, Group A5, Group B5), after the whitening, 10% sodium ascorbate (Acros Organics, Geel, Belgium) was implemented on the enamel surface of the samples at a flow rate of 1 ml per minute for 10 minutes. Then, the enamel surfaces of the samples were rinsed with distilled water for 30 seconds.

Bonding Procedure

Control (Group A1 and Group B1), immediate bonding (Group A2, Group B2, Group A4, Group B4) and antioxidant groups (Group B3, Group A3, Group A5, Group B5) were divided into two groups for bonding with Single Bond 2 (Group A) (3M ESPE, USA) or Clearfil SE (Group B) (Kuraray, Japan) (n =10 each). The composition of the adhesive systems and bonding procedures showed in Table 1. Each tooth was placed into a special Teflon mold (Ultradent Product, Inc., Utah, USA) with a standardized central hole (3 mm in diameter) to restore with the composite (Clearfil ST, Kuraray, Japan). Two increments of a composite resin were placed into the aperture of the Teflon mold, and then each increment were cured for 40 seconds with photocuring unit. The composite cylinder blocks were additionally cured for 40 seconds from different sides, after the removing Teflon mold, to provide the maximum polymerization of the composite resin. After polymerization, each sample was placed in a special device that was fitted on the universal testing machine (Elista, Istanbul, Turkey). The direction of the plunger was adjusted parallel to the flat enamel surface and the crosshead speed was set at 1 mm per minute. The load continuously recorded by a software system and was monitored at failure (Elista, Tensile test systems, Istanbul, Turkey). Fracture analysis of the attached enamel surface was conducted with a stereomicroscope (Olympus Co, Tokyo, Japan) at 16x magnification.

Statistical analysis of this in vitro study was performed with a SPSS 15.0 software system (SPSS Inc., Chicago, USA). Two-way analysis of variance (ANOVA) test was used to compare the mean shear bond strength data obtained from the groups. Then, Tukey's test was used for multiple comparisons between means, to determine significant differences with a significance level set at $p<0.05$.

RESULTS

The mean shear bond strengths data in MPa for all groups are shown in Table 2. The two-way analysis of variance indicated significant differences in shear bond strengths values among the groups ($P <0.05$). The composite restorations were made with both two adhesive systems immediately after the whitening showed significantly lower shear bond strengths values then those of composite restorations made on non-whitened enamel ($p<0.05$). No statistically significant differences in mean shear bond strengths values were found for two adhesive systems, when the antioxidant-treated groups were compared with the non-whitened group (Control) ($p>0.05$). The Table 2 compares the mean shear bond strengths values of the different composite restorations groups. The shear bond strengths values of both two adhesive systems decreased after whitening but reversed after sodium ascorbate application. This showed that antioxidant treatment has a statistically significant effect at reversing the shear bond strength values of two adhesive systems to whitened enamel.

Adhesive Systems	Principal Ingredients	Steps of Applications
Clearfil SE Bond Primer	Hydrophilic aliphatic dimethacrylate, MDP, phosphoric acid acrylate, water, stabilisers	Apply primer, leave for 20s, air-dry
Bond	HEMA, Bis-GMA, MDP, Hydrophobic aliphatic dimethacrylate, colloidal silica, initiators and stabilisers	Apply Bond, air-thin, light-cure for 10s.
Single Bond 2	Bis-GMA, BPDM, HEMA, Dimethacrylates, Ethanol, spherical silica particles, water,	Etch 15s, wash acid gel, air-dry for 2-3 seconds, apply Bond, air-thin and light-cure for 10s.

Table 1. Chemical Compositions and Bonding Procedures of the Dentine Bonding Systems

Bis-GMA: Bisphenol-Glycidyl-Methacrylate; HEMA: 2-Hydroxyethyl Methacrylate; BPDM: Biphenyl Dimethacrylate; MDP: 10-Methacryloxdecyl Dihydrogen Phosphate.

Groups		n	Mean ± SD (MPa)*
Group A Single Bond 2 3M, Espe; Germany	Group A1 (NC-Non whitened)	10	30.27 ± 6.55[a]
	Group A2 (CP -Immediately)	10	24.01 ± 5.42[c]
	Group A3 (CP-10% sodium ascorbate)	10	31.45 ± 4.86[ae]
	Group A4 (HP- Immediately)	10	20.86 ± 3.93[b]
	Group A5 (HP-10% sodium ascorbate)	10	28.85 ± 6.35[a]
Group B Clearfil SE Bond Kuraray; Japan	Group B1 (NC- Non whitened)	10	38.94 ± 8.23[d]
	Group B2 (CP-Immediately)	10	31.13 ± 3.36[ae]
	Group B3 (CP-10% sodium ascorbate)	10	39.16 ± 7.42[d]
	Group B4 (HP-Immediately)	10	19.99 ± 4.72[b]
	Group B5 (HP-10% sodium ascorbate)	10	32.78 ± 5.28[e]

Table 2. Mean Shear Bond Strength Values and Standard Deviations of Groups

*Different superscripts uppercase letters in each column indicate statistically significant differences ($p < 0.05$).

DISCUSSION

This in-vitro study investigated the effects of antioxidant treatment after whitening with CP and HP on the shear bond strength of two different dental adhesives. Based on the results of this in-vitro study, and due to significant effects of the antioxidant treatment on the results, the null hypothesis was rejected.

In the present study, it was observed that whitening procedures with both 15% CP and 35% HP resulted in a significant decrease of bond strength values on enamel in both bonding systems (Table 2). There have been many studies that have been reporting a reduced bond strength of composite resin to CP-whitened enamel when compared with non-whitened enamel.[10,11,16,18,22,24,30] The results of our in-vitro study revealed a significant reduction in the shear bond strength values of both two bonding systems when the restoration is done immediately after 15% CP whitening. In a study by Bulut et al.[30] Showed that 10% CP whitening decreased the shear bond strength of brackets when bonded immediately after whitening. In a study of Turkun and Kaya[11], on the shear bond strength of bonding composites to whitened bovine enamel surfaces with different concentrations of (10%, 16% and 22%) CP showed that all three concentrations reduced the bond strength values. The higher concentration of whitening agent caused a more significant reduction in shear bond strength than the lower concentration.[11] Therewithal, there are many studies reporting decreased in the bond strength of composite to whitened enamel with HP.[29,31]

A number of reasons have been suggested to explain the reduction in enamel bond strength resulting from the whitening procedures. Whitening agents release free radicals when they are applied to the enamel surface.[32] The peroxide free radical is any molecule that has one unpaired electron, giving it high reactivity.[32] These free radicals are capable of to react with the electron-rich regions of the pigmented molecules inside the dental structure, and could break down large pigmented molecules into smaller, less pigmented ones.[29] Residual free radicals present inside the tooth structure may affect the polymerization process of the bonding resin materials and inhibits the adhesion to the tooth structure.[12,19,23,33]

Oxygen which develops on the enamel surface from the whitening agent prevents resin polymerization or interferes with resin penetration into the etched enamel.[11,19,33] Potocnik et al.[34] Examined the changes in the lower surface of the enamel layer after using 10% carbamide peroxide with scanning electron microscopy and local changes similar to initial caries demineralization were observed. They also reported that the calcium and phosphorus ratio was reduced, however these reduce were not has a clinically meaningful acceptance.[34] Loss of calcium leads to a decrease in microhardness of the enamel surface and alterations in the inorganic substance may also be a factor for reducing the bond strengths.[34-36] Several electron microscopic studies observed that the resin tags in whitened enamel were short, poorly defined, structurally incomplete, and, in some areas, completely absent.[12,19,37] Torneck et al.[38] Reported that alterations in resin quality after whitening with 35% HP were because of the presence of residual free oxygen radicals or oxygen -related compounds at or near the enamel surface. Therewithal dentin and dentinal fluid can act as a oxygen reservoir.[39]

Previous studies have shown that 10% sodium ascorbate treatment is effective in increasing decreased bonding strength by whitening agent.[11,17,29,40] Vitamin C and its salts are nontoxic and can be used safely intra-orally.[17,29] In our in vitro this study, the sodium ascorbate application to the whitened enamel increased the shear bond strength values. For the study by Lai et al.[17] 10% sodium ascorbate have to be applied at whitened enamel surface for at least one-third of the whitening time or near that time, otherwise may not be enough for clinical application. In more recent studies, application for 10 minutes of antioxidant was tested, which is the same as in our in-vitro study, and appear to be more suitable for clinical conditions.[11,30,32] In this study, the teeth were whitened for a total of 30 minutes with 35% HP Office-whitening gel, and sodium ascorbate applied for 10 minutes. Sodium ascorbate was applied to the CP home whitening gel group for the same length of time. In the present study, it was observed that the application of 10% antioxidant-agent treatment resulted in greater bond strength means (Table 2). Our results agree with previous studies that have shown that the decreased shear bond strength of bonded composite resin to whitened enamel was fully restored by antioxidant application to the whitened enamel.

CONCLUSIONS

Whitening with 35% HP or 15% CP immediately before a bonding procedure decreases the shear strength of composite resin to whitened enamel bond. The treatment of the whitened enamel with an antioxidant such as 10% sodium ascorbate restores the bond strength of both adhesive systems. If restoration has to be completed immediately after whitening, anti-oxidant application is an alternative to postpone the restoration. Further studies are needed to decide the required application times for efficient neutralizing using high concentrations of antioxidant agents.

REFERENCES

[1] Blankenau R, Goldstein RE, Haywood VB. The current status of vital tooth whitening techniques. Compend Contin Educ Dent 1999;20(8):781-4.

[2] Attin T, Hannig C, Wiegand A, et al. Effect of bleaching on restorative materials and restorations -- a systematic review. Dent Mater 2004;20(9):852-61.
[3] Tavares M, Stultz J, Newman M, et al. Light augments tooth whitening with peroxide. J Am Dent Assoc 2003;134(2):167-75.
[4] Haywood VB, Heymann HO. Nightguard vital bleaching. Quintessence Int 1989;20(3):173-6.
[5] Kihn PW, Barnes DM, Romberg E, et al. A clinical evaluation of 10 percent vs. 15 percent carbamide peroxide tooth-whitening agents. J Am Dent Assoc 2000;131(10):1478-84.
[6] Oltu U, Gurgan S. Effects of three concentrations of carbamide peroxide on the structure of enamel. J Oral Rehabil 2000;27(4):332-40.
[7] Kugel G, Perry RD, Hoang E, et al. Effective tooth bleaching in 5 days: using a combined in-office and at-home bleaching system. Compend Contin Educ Dent 1997;18(4):378, 380-3.
[8] Christensen GJ. Bleaching teeth: practitioner trends. J Am Dent Assoc 1997;128 Suppl:16S-18S.
[9] Titley KC, Torneck CD, Smith DC, et al. Adhesion of composite resin to bleached and unbleached bovine enamel. J Dent Res 1988;67(12):1523-8.
[10] Garcia-Godoy F, Dodge WW, Donohue M, et al. Composite resin bond strength after enamel bleaching. Oper Dent 1993;18(4):144-7.
[11] Turkun M, Kaya AD. Effect of 10% sodium ascorbate on the shear bond strength of composite resin to bleached bovine enamel. J Oral Rehabil 2004;31(12):1184-91.
[12] Titley KC, Torneck CD, Smith DC, et al. Scanning electron microscopy observations on the penetration and structure of resin tags in bleached and unbleached bovine enamel. J Endod 1991;17(2):72-5.
[13] Stokes AN, Hood JA, Dhariwal D, et al. Effect of peroxide bleaches on resin-enamel bonds. Quintessence Int 1992;23(11):769-71.
[14] Toko T, Hisamitsu H. Shear bond strength of composite resin to unbleached and bleached human dentine. Asian J Aesthet Dent 1993;1(1):33-6.
[15] Miles PG, Pontier JP, Bahiraei D, et al. The effect of carbamide peroxide bleach on the tensile bond strength of ceramic brackets: an in vitro study. Am J Orthod Dentofacial Orthop 1994;106(4):371-5.
[16] Ben-Amar A, Liberman R, Gorfil C, et al. Effect of mouthguard bleaching on enamel surface. Am J Dent 1995;8(1):29-32.
[17] Lai SC, Tay FR, Cheung GS, et al. Reversal of compromised bonding in bleached enamel. J Dent Res 2002;81(7):477-81.
[18] Josey AL, Meyers IA, Romaniuk K, et al. The effect of a vital bleaching technique on enamel surface morphology and the bonding of composite resin to enamel. J Oral Rehabil 1996;23(4):244-50.
[19] Dishman MV, Covey DA, Baughan LW. The effects of peroxide bleaching on composite to enamel bond strength. Dent Mater 1994;10(1):33-6.
[20] Rotstein I. Role of catalase in the elimination of residual hydrogen peroxide following tooth bleaching. J Endod 1993;19(11):567-9.
[21] Barghi N, Godwin JM. Reducing the adverse effect of bleaching on composite-enamel bond. J Esthet Dent 1994;6(4):157-61.
[22] Cvitko E, Denehy GE, Swift EJ, et al. Bond strength of composite resin to enamel bleached with carbamide peroxide. J Esthet Dent 1991;3(3):100-2.
[23] Kalili T, Caputo AA, Mito R, et al. In vitro toothbrush abrasion and bond strength of bleached enamel. Pract Periodontics Aesthet Dent 1991;3(5):22-4.
[24] Sung EC, Chan SM, Mito R, et al. Effect of carbamide peroxide bleaching on the shear bond strength of composite to dental bonding agent enhanced enamel. J Prosthet Dent 1999;82(5):595-9.
[25] Turkun M, Sevgican F, Pehlivan Y, et al. Effects of 10% carbamide peroxide on the enamel surface morphology: a scanning electron microscopy study. J Esthet Restor Dent 2002;14(4):238-44.
[26] Spyrides GM, Perdigao J, Pagani C, et al. Effect of whitening agents on dentin bonding. J Esthet Dent 2000;12(5):264-70.
[27] Van der Vyver PJ, Lewis SB, Marais JT. The effect of bleaching agent on composite/enamel bonding. J Dent Assoc S Afr 1997;52(10):601-3.
[28] Cavalli V, Reis AF, Giannini M, et al. The effect of elapsed time following bleaching on enamel bond strength of resin composite. Oper Dent 2001;26(6):597-602.
[29] Lai SC, Mak YF, Cheung GS, et al. Reversal of compromised bonding to oxidized etched dentin. J Dent Res 2001;80(10):1919-24.
[30] Bulut H, Turkun M, Kaya AD. Effect of an antioxidizing agent on the shear bond strength of brackets bonded to bleached human enamel. Am J Orthod Dentofacial Orthop 2006;129(2):266-72.
[31] Unlu N, Cobankara FK, Ozer F. Effect of elapsed time following bleaching on the shear bond strength of composite resin to enamel. J Biomed Mater Res B Appl Biomater 2008;84(2):363-8.
[32] Torres CRG, Koga AF, Borges AB. The effects of anti-oxidant agents as neutralizers of bleaching agents on enamel bond strength. Brazilian Journal of Oral Sciences 2006;5(16):971-6.
[33] McGuckin RS, Thurmond BA, Osovitz S. Enamel shear bond strengths after vital bleaching. Am J Dent 1992;5(4):216-22.
[34] Potocnik I, Kosec L, Gaspersic D. Effect of 10% carbamide peroxide bleaching gel on enamel microhardness, microstructure and mineral content. J Endod 2000;26(4):203-6.
[35] McCracken MS, Haywood VB. Demineralization effects of 10 percent carbamide peroxide. J Dent 1996;24(6):395-8.
[36] Hegedus C, Bistey T, Flora-Nagy E, et al. An atomic force microscopy study on the effect of bleaching agents on enamel surface. J Dent 1999;27(7):509-15.
[37] Sundfeld RH, Briso AL, De Sa PM, et al. Effect of time interval between bleaching and bonding on tag formation. Bull Tokyo Dent Coll 2005;46(1-2):1-6.
[38] Torneck CD, Titley KC, Smith DC, et al. The influence of time of hydrogen peroxide exposure on the adhesion of composite resin to bleached bovine enamel. J Endod 1990;16(3):123-8.

[39] Titley KC, Torneck CD, Ruse ND, et al. Adhesion of a resin composite to bleached and unbleached human enamel. J Endod 1993;19(3):112-5.

[40] Comlekoglu ME, Gokce B, Kaya AD, et al. Reversal of reduced bond strength after bleaching. Gen Dent 2010;58(3):258-63; quiz 264-5.