Comparative Analysis of Shear Bond Strength of Composites to the Sodium Ascorbate Hydrogel-treated Bleached Enamel Surfaces: An In Vitro Analysis

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ABSTRACT

Aim: To compare the shear bond strength of composites to the sodium ascorbate hydrogel-treated bleached enamel surfaces.

Materials and methods: Sixty-six extracted human maxillary first premolars were sectioned mesiodistally to obtain two nonocclusal surfaces (n = 132). The specimen in the experimental group (n = 80) were divided into four treatment groups depending upon bleaching protocols used: group I (10% FGM home bleach), group II (22% Pola Night home bleach), group III (37% light-activated in-office bleach Pola Office+), and group IV (35% Pola office in-office bleach without light activation). Specimens were subjected to the 1-minute application twice with sodium ascorbate hydrogel and were further divided into two subgroups “a” (acetone-based) and “b”(ethanol-based) depending upon the bonding agents used. The specimens of the control group (n = 52) were further divided into two treatment groups, that is, positive control and negative control. The specimens were tested using universal testing machine.

Results: The result of the present study revealed that the specimens bleached with 10% FGM home bleach showed the greatest shear bond strength and specimens bleached with 35% in-office bleach Pola Office showed the lowest shear bond strength.

Conclusion: A twice 1-minute application of sodium ascorbate hydrogel was effective to reverse the deleterious results of bleaching on enamel shear bond strength. Bonding agent containing acetone as a solvent (Prime and Bond NT) in this present study showed greater shear bond strength values than the bonding agent containing ethanol as a solvent (Adper Single Bond).

Statement of clinical relevance: The shear bond strength of composite restorative materials could be improved by applying sodium ascorbate gel to the bleached enamel surfaces.

Keywords: Bleaching agents, Bonding agents, Composite restorations, Sodium ascorbate hydrogel.

INTRODUCTION

Bleaching of discolored teeth has been one of the most conservative and economical methods of improving the appearance of an individual. After bleaching, the tooth significantly becomes lighter shade when compared to the previous shade. Though, the tooth shade becomes lighter, preexisting restoration if any on the bleached tooth remains the same. The difference in the shade of preexisting restoration with bleached tooth warrants a replacement of preexisting restoration with a new restoration.

Bond strength to the restorative materials could be reduced after bleaching of the enamel, and it can be due to the interference of residual peroxides with resin tag formation. Restorative procedures should be delayed to reverse the aforementioned effect, and it was also postulated that antioxidants can be used to reverse effects of bleaching agents.

Free radicals remaining in the tooth structure after bleaching react with antioxidants and thus indirectly aids in increasing the bond strength of tooth structure and restorative materials. Sodium ascorbate was proposed in the literature to aid in improving the bond strength of restorative materials to the bleached enamel surfaces.

The present study aims to compare the shear bond strength of bleached enamel using different bleaching protocols with two different bonding agents after application of sodium ascorbate hydrogel. The null hypothesis states that “there would be no effect on shear bond strength of bleached enamel surface” after the application of antioxidant sodium ascorbate hydrogel.

MATERIALS AND METHODS

Sixty-six human maxillary first premolars extracted for periodontal reasons were collected. Institutional ethical clearance was obtained for the present study with an ethical approval number-DDCH/ADM/2016-17/1391-CD&E. Carious teeth, teeth with restorations, and teeth with cracks or fractures were excluded from the study.

The present study aims to compare the shear bond strength of bleached enamel using different bleaching protocols with two different bonding agents after application of sodium ascorbate hydrogel. The null hypothesis states that “there would be no effect on shear bond strength of bleached enamel surface” after the application of antioxidant sodium ascorbate hydrogel.
cracks/fractures, carious lesions, and developmental defects were not included. The teeth were washed under running tap water to remove blood and saliva and were rendered free of calculus and other soft tissue debris using an ultrasonic scaler. The samples were further stored in distilled water at room temperature.

**Preparation of Samples**

Samples were prepared by removing the roots of the teeth utilizing a high-speed diamond disk attached to the dental micromotor headpiece. Each test sample’s crown was sectioned mesiodistally in order to attain two nonocclusal enamel surfaces (Fig. 1) and thus 132 samples were obtained.

A silicone mold was prepared and test samples were mounted in acrylic resin to expose the enamel surface (Fig. 2). Test samples were further polished using 320 grit silicone carbide papers to get standard flat enamel surface.

**Sample Distribution**

**Experimental Group**

The test samples were randomly divided into four treatment groups with 20 samples in each treatment group, that is, groups I, II, III, and IV depending upon bleaching protocols used. The test groups were further divided into subgroups “a” [Fifth generation acetone-based (Prime and Bond NT, DENTSPLY Caulk)] and ‘b’ [Fifth generation ethanol-based (Adper Single Bond, 3M ESPE)] depending upon bonding agents used.

**Control Group**

The positive control group was in which the samples were not bleached and bonded with acetone-based and ethanol-based bonding agents. The negative control group was in which the samples were bleached using four different bleaching agents and any of the two bonding (acetone or ethanol) systems were used for bonding.

**Bleaching Procedure**

Test samples in groups I and II were treated with 10 and 22% carbamide peroxide home bleaching agents [FGM (whiteness perfect) Joinville, SC Brazil Home Bleach and Pola Night (SDI), respectively] and test samples of groups III and IV were bleached with [light-activated Pola Office + (SDI) and nonlight activated In-office bleach Pola Office (SDI), respectively] as per manufacturer’s instructions (Fig. 3).

**Preparation of Sodium Ascorbate Hydrogel (Antioxidant Gel)**

Sodium ascorbate solution (32%) was prepared by dissolving sodium ascorbate in pure water at normal room temperature. Carbopol gel [2.5% (wt/wt)] was prepared by mixing carbopol resin with sodium ascorbate solution. The mixture was thickened by stirring and was then neutralized adding triethanolamine (TEA), and the pH was adjusted to 7.

**Application of Sodium Ascorbate Hydrogel**

After bleaching the test samples 32% sodium ascorbate hydrogel was applied twice for 1 minute each on enamel surfaces of the embedded specimen in the experimental group. Test samples were immersed for 10 minutes in distilled water to dissolve sodium ascorbate on enamel surface.

**Bonding Procedure and Composite Placement**

Test samples were etched using phosphoric acid (37%) for 15 to 30 seconds. After etching of the test samples, fifth-generation “acetone-based” (Prime and Bond NT, DENTSPLY Caulk) and “ethanol-based” (Adper Single Bond, 3M ESPE) bonding agents were applied to enamel surfaces of all test samples (Fig. 4). A plastic...
Preparation of the Control Group Sample

In the positive control group V \((n = 20)\) specimens were not bleached and were directly bonded with acetone-based \((n = 10)\) and ethanol-based \((n = 10)\) bonding agents and composite build-up was done. In negative control group, test samples of group VI and VII \((n = 8\) in each group) were subjected to 10 and 22% carbamide peroxide home bleaching agents, respectively. Samples in group VIII and group IX \((n = 8\) in each group) were subjected to 37% hydrogen peroxide light-activated and 35% hydrogen peroxide non-light-activated in-office bleaching agents, respectively using a similar technique in the experimental group. The samples were further divided based upon the bonding agents used \((n = 4)\) and composite build-up done using a similar technique in the experimental group. The division of experimental and control group specimens according to the materials used are presented in Figure 5.

Shear Bond Strength Testing

Test samples were mounted and shear stress was applied at the rate of 1.5 mm/min using Universal testing machine (ASI, Delhi) with a knife edged loading head.

Statistical Analysis

The descriptive statistical analysis was done in all the experimental and control groups and means ± standard deviation (SD) values...
were derived. The data for each group were analyzed using One-way analysis of variance (ANOVA) and Student t-test. Statistical analysis was done using *SPSS software version 21* and a p-value of less than or equal to 0.05 was considered as statistically significant.

## Results

Shear bond strength values of all the test samples were analyzed and mean ± SD values are presented in Table 1. The mean and SD of the various experimental and negative control groups are presented in Table 2. As per the result of this study, it was observed that the specimens which received sodium ascorbate hydrogel application after bleaching and later were bonded using any of the bonding systems presented higher shear bond strength (p < 0.001) when compared to those groups that did not receive any sodium ascorbate hydrogel treatment. Table 2 shows test samples bonded with Prime and Bond NT. Fifth-generation acetone-based bonding agent shows more shear bond strength values than the test samples bonded with Adper Single Bond, that is, ethanol-based bonding agent (p < 0.001) irrespective of different bleaching protocols used.

The comparison between bond strengths achieved after using acetone-based and ethanol-based bonding agents in positive control group samples is presented in Table 3. The samples prepared using acetone-based bonding agents showed higher shear strength values than the ethanol-based bonding agents (p < 0.001). These intergroup comparisons of various shear bond strengths achieved with different concentrations of bleaching agents are represented in Table 4. Highest shear bond strength was observed when test samples were bleached with 10% carbamide peroxide home bleach irrespective of the bonding agent used. Similarly, the lowest shear bond strength is observed in specimens subjected to 35% hydrogen peroxide nonlight activated in-office bleach irrespective of different bonding agents used.

### Discussion

Bleaching agents usually contain different concentrations of carbamide peroxide/hydrogen peroxide and can cause alteration in the tooth substrate.

Oxygen-free radicals were released by the bleaching agents on to the enamel surfaces and they inhibit polymerization of the composite materials, which results in a granular and porous bubbled appearance of resin-bleached enamel interface. Thus immediately after bleaching a lower hardness values were observed on the enamel surfaces. Peroxide apatite crystals were produced in the enamel as the peroxide ions replace hydroxyl ions in apatite crystals. The replacement process can be reversed by the application of antioxidants on enamel surfaces. Buffering action of saliva requires at least 24 hours to 3 weeks to remove free radicles present on enamel surface and thus the restorative procedure need to be suspended during the recommended time. Sodium ascorbate has been traditionally used as an antioxidant considering its ability to neutralize and/or reverse the oxidizing effect of peroxide containing materials. Neutralization from antioxidant agents to free radicals is categorized into three types firstly continuous full-time prevention, second active detoxification of oxidative stress, and third passive detoxification. Sodium ascorbate is included in passive detoxification that can neutralize free radicals and belong to nonenzyme antioxidants. Results of this study are in accordance with the published reports where sodium ascorbate aids in reversing the effects of bleaching agents on bonding of restorative materials.

Sodium ascorbate gel was used instead of solution in the present study as the gel forms have more acceptability in clinical scenarios as manipulation of solution is more difficult than gels. The mode of delivery both in terms of concentration and duration of application are important factors in reversing the effects

### Table 1: Shear bond strength values of the experimental and control (positive and negative) group samples

| S. No | Group | Subgroup (sample) | Mean ± SD | p-value |
|-------|-------|-------------------|-----------|---------|
| 1     | Experimental group | a b | 53.29 ± 4.60 | 4.12 ± 1.26 |
| 2     | Positive control group | a b | 60.8 ± 4.60 | 4.12 ± 1.26 |
| 3     | Negative control group | a b | 60.8 ± 4.60 | 4.12 ± 1.26 |

*Shear bond strength values were presented in the units of MPa in all the test samples*

### Table 2: Comparative analysis of shear bond strength between the experimental and negative control groups

| S. No | Group | Mean ± SD | p-value |
|-------|-------|-----------|---------|
| 1     | Experimental group using acetone-based bonding agents | 40.8 ± 11.63 | < 0.001* |
| 2     | Negative control group using acetone-based bonding agents | 11.6 ± 6.77 | < 0.001* |
| 3     | Experimental group using ethanol-based bonding agents | 29.7 ± 10.24 | < 0.001* |
| 4     | Negative control group using ethanol-based bonding agents | 9.2 ± 6.56 | < 0.001* |

*p value of < 0.05 was considered as statistically significant.*
Shear Bond Strength of Sodium Ascorbate-treated Bleached Enamel Surfaces

Different concentrations (2.5, 5, and 10%) of sodium ascorbate were tested and agents with concentration less than 10% are not sufficient to reverse the effects of bleaching agents. It was also reported that the amount of sodium ascorbate required to neutralize the effects of bleaching agents is proportional to the concentration of bleaching agents used.

In the present study, the bleached enamel was exposed to sodium ascorbate as per recommendations in the past literature (two applications of 1 minute each). The methodology used in the present study was different from past literature, where longer duration of applications (10 minutes to 6 hours) were tested. It was reported that the frequency of applications is more vital than the contact time of sodium ascorbate. The reaction of oxide-free radicals and antioxidants reach the maximum in 1 minute and thus increasing the duration of contact time of sodium ascorbate cannot remove more free radicals.

A commonly used in-office bleaching system with or without the light activation and home bleaching systems with different concentrations were used, and it was found that specimen bleached with 10% FGM home bleach, that is, group I showed greater shear bond strength as compared to other experimental and control groups. The possible explanation could be that the application of sodium ascorbate immediately after use of carbamide peroxide increased the length of resin tag formation and the present study results are in accordance with the past literature. Sodium ascorbate is, however, less effective in teeth bleached with greater concentrations of carbamide peroxide with higher concentrations of oxygen being released.

It was reported that use of 35% hydrogen peroxide is more deleterious for resin tag formation than 10% carbamide peroxide. Ten percent carbamide peroxide releases 3% hydrogen peroxide and 7% urea; this is 10 times lower than 35% concentration of carbamide peroxide. Therefore, the results of our present study were in concurrence with the available scientific data, which states lower bond strength values when the greater concentration of hydrogen peroxide is used and antioxidant agents were not able to neutralize the effects of bleaching agents on bond strength. Bleached test samples in the negative control group, which were bleached and immediately restored using composite resin without any antioxidant treatment reported the least bond strength values and the presumable reason was that the residual oxygen released by bleaching agents on the enamel surface inhibit the polymerization of bonding agents.

Specimens of positive control group, that is, specimens that were not bleached and were directly bonded with acetone and ethanol-based bonding agent also showed the statistically significant difference in their bond strength value, with higher bond strength in samples bonded with acetone-based bonding agent when compared to specimens bonded with the ethanol-based bonding agent. The reason behind the above results may be because acetone plays an important role to displace the water from tooth surface and results in better bond strength which was in accordance with the past literature.

Light sources have greater potential for whitening teeth because they produce necessary heat for activating the hydrogen peroxide. The use of the light source for activation of bleaching agents is optional, and the effect of light sources is at times controversial. Some believe that it is very effective in bleaching the tooth structure, while others report only certain lights are effective. Various factors determine the controversial results such as baseline color of the teeth, concentration of bleaching agents used, and duration of the treatment.

In the present study, specimens of group III bleached with 37% hydrogen peroxide in-office bleaching system Pola office+ with light activation showed greater bond strength value in comparison to specimens of group IV bleached with 35% hydrogen peroxide in-office bleaching system Pola office without light activation. The possible explanation could be due to better polymerization and release of less oxygen-free radicals from the bleaching agents after exposure to light source resulting in greater bond strength values. This may be justified by the fact that the light-activation system produces good instant bleaching effects than the nonlight-activation systems with less concentrated hydrogen peroxide.

Considering the above findings and results, the hypothesis of the present study was rejected where the application of sodium ascorbate antioxidant hydrogel significantly increased the shear bond strength of bleached enamel surfaces.

| S. No | Type of bonding agent | Group | Mean ± SD | p-value |
|-------|-----------------------|-------|-----------|---------|
| 1 | Acetone-based bonding agent | G Ia | 53.2 ± 4.6 | <0.001 |
| | | G Ila | 39.6 ± 1.74 | |
| | | G Ila | 47 ± 2.59 | |
| | | G 1Va | 23.5 ± 2.23 | |
| 2 | Ethanol-based bonding agent | G Ib | 41.2 ± 1.25 | <0.001 |
| | | G Ilb | 21.6 ± 1.5 | |
| | | G Ilb | 37.8 ± 2.09 | |
| | | G 1Vb | 18.3 ± 3.12 | |

*p value of <0.05 was considered as statistically significant
Shear Bond Strength of Sodium Ascorbate-treated Bleached Enamel Surfaces

Limitations

Though every effort was taken to mimic the oral conditions, thermocycling of the test samples was not done in the present study. Secondly, the influence of dynamic or cyclic load testing was not in the present study which may limit the recommendation present study results to the clinical practice. Thus, the results of this in vitro study need to be cautiously implemented in the clinical scenario, and in vivo and randomized controlled trials are indicated to reinforce the present study results.

Conclusion

A twice 1-minute application of sodium ascorbate hydrogel was effective in neutralizing the deleterious effects of bleaching agents on enamel shear bond strength. Bonding agent containing acetone as a solvent (Prime and Bond NT) showed greater shear bond strength values than the bonding agent containing ethanol as a solvent (Adper Single Bond). As the concentration of bleaching agents increases from 10 to 37%, the shear bond strength decreases except for the specimens bleached with a 35% light-activated system.

Clinical Significance

The use of sodium ascorbate gel on the bleached enamel surfaces with acetone-based bonding agents improved the shear bond strength of the restorative composite materials.

References

1. Benni DB, Naik SN, Subbareddy VV. An in vitro study to evaluate the effect of two ethanol-based and two acetone-based dental bonding agents on the bond strength of composite to enamel treated with 10% carbamide peroxide. J Indian Soc Pedod Prev Dent 2014;32(3):207–211. DOI: 10.1016/j.jspi.2014.07.001

2. Briso AL, Toseto RM, Rahal V, et al. Effect of sodium ascorbate on tag formation in bleached enamel. J Adhes Dent 2012;14(1):19–23. DOI: 10.3290/j.jad.a21402

3. Lai SC, Mak YF, Cheung GS, et al. Reversal of compromised bonding to oxidized etched dentin. J Dent Res 2001;80(10):1919–1924. DOI: 10.1177/00220345010800101101

4. Kimyai S, Valizadeh H. The effect of hydrogel and solution of sodium ascorbate on bond strength in bleached enamel. Oper Dent 2006;31(4):496–499. DOI: 10.2341/05-65-05-85.

5. Sirisha K, Rambabu T, Ravishankar Y, et al. Validity of bond strength tests: a critical review-Part II. J Conserv Dent 2014;17(5):420–426. DOI: 10.4103/0972-0707.139823

6. Nari-Ratih D, Widyastuti A. The effect of antioxidants on the shear bond strength of composite resin to enamel following extra-coronal bleaching. J Clin Exp Dent 2019;11(2):e126–e132. DOI: 10.4317/jced.55359

7. Dabas D, Patil AC, Uppin VM. Evaluation of the effect of concentration and duration of application of sodium ascorbate hydrogel on the bond strength of composite resin to bleached enamel. J Conserv Dent 2011;14(4):356–360. DOI: 10.4103/0972-0707.87197

8. Murad CG, de Andrade SN, Disconzi LR, et al. Influence of 10% sodium ascorbate gel application time on composite bond strength to bleached enamel. Acta Biomater Odontol Scand 2016;2(1):49–54. DOI: 10.3109/23337931.2016.1152901

9. Egulla A, Pranitha V, Dwijendra KS, et al. Reversal of compromised bond strength of bleached enamel using cranberry extract as an antioxidant: an in vitro study. Cureus 2019;11(11):e6188. DOI: 10.7759/cureus.6188

10. Kavitha M, Selvaraj S, Khetarpal A, et al. Comparative evaluation of superoxide dismutase, alpha-tocopherol, and 10% sodium ascorbate on reversal of shear bond strength of bleached enamel: an in vitro study. Eur J Dent 2016;10(1):109–115. DOI: 10.4103/1305-7456.175693

11. Garcia EJ, Oldoni TL, Alencar SM, et al. Antioxidant activity by DPPH assay of potential solutions to be applied on bleached teeth. Braz Dent J 2012;23(1):22–27. DOI: 10.1590/s0103-64402012000100004

12. Lai SC, Tay FR, Cheung GS, et al. Reversal of compromised bonding in bleached enamel. J Dent Res 2002;81(7):477–481. DOI: 10.1177/154405910208100709

13. Kaya AD, Türkün M. Reversal of dentin bonding to bleached teeth. Oper Dent 2003;28(6):825–829. PMID: 14653300.

14. Nascimento GCR, Ribeiro MES, Guerreiro MYR, et al. Effect of sodium ascorbate on bond strength and metalloproteinases activity in bleached dentin. Clin Cosmet Investig Dent 2019;11:259–265. DOI: 10.2147/CCIDC.S209278

15. Hansen JR, Frick KJ, Walker MP. Effect of 35% sodium ascorbate treatment on microtensile bond strength after nonvital bleaching. J Endod 2014;40(10):1668–1670. DOI: 10.1016/j.jdent.2014.06.001

16. Freire A, Souza EM, de Menezes Caldas DB, et al. Reaction kinetics of sodium ascorbate and dental bleaching gel. J Dent 2009;37(12):932–936. DOI: 10.1016/j.jdent.2009.07.008

17. Feiz A, Khoroushi M, Gheisarifar M. Bond strength of composite resin to bleached dentin: effect of using antioxidant versus buffering agent. J Dent (Tehran) 2011;8(2):60–66. PMID: 21998810.

18. Coppla FM, Freire A, Bittencourt B, et al. Influence of simplified, higher-concentrated sodium ascorbate application protocols on bond strength of bleached enamel. J Clin Exp Dent 2019;11(1):e21–e26. DOI: 10.4317/jced.55153

19. Freire A, Durski MT, Inbergeman M, et al. Assessing the use of 35 percent sodium ascorbate for removal of residual hydrogen peroxide after in-office tooth bleaching. J Am Dent Assoc 2011;142(7):836–841. DOI: 10.14219/jada.archive.2011.0273

20. Garcia EJ, Mena-Serrano A, de Andrade AM, et al. Immediate bonding to bleached enamel treated with 10% sodium ascorbate gel: a case report with one-year follow-up. Eur J Esthet Dent 2012;7(2):154–162. PMID: 22645730.

21. Kimyai S, Oskoei SS, Rafghi A, et al. Comparison of the effect of hydrogel and solution forms of sodium ascorbate on orthodontic bracket-enamel shear bond strength immediately after bleaching: an in vitro study. Indian J Dent Res 2010;21(1):54–58. DOI: 10.4103/0970-9290.62818

22. Uysal T, Ertas H, Sagens B, et al. Can intra-coronally bleached teeth be bonded safely after antioxidant treatment? Dent Mater J 2010;29(1):47–52. DOI: 10.4103/dmj.2009.064

23. Sasaki RT, Flório FM, Basting RT. Effect of 10% sodium ascorbate and 10% alpha-tocopherol in different formulations on the shear bond strength of oxidized dentin. J Conserv Dent 2006;31(4):496–499. DOI: 10.2341/05-65-05-85.

24. Cunha S, Oskoei SS, Mafra DJ, et al. Bond strength of composite resin to bleached teeth after antioxidant treatment: a randomized clinical study. Dent Mater 2013;29(5):601–606. DOI: 10.1016/j.dental.2013.02.012

25. Türkün M, Kaya AD. Effect of an oxidizing agent on the shear bond strength of brackets bonded to bleached human enamel. Am J Orthod Dentofacial Orthop 2006;129(2):266–272. DOI: 10.1016/j.ajodo.2004.03.043

26. Bulut H, Kaya AD, Türkün M. Tensile bond strength of brackets after antioxidant treatment on bleached teeth. Eur J Orthod 2005;27(3):461–471. DOI: 10.1093/ejo/cji044

27. Türkün 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):1184–1191. DOI: 10.1111/j.1365-2842.2004.01369.x

28. Sun G. The role of lasers in cosmetic dentistry. Dent Clin North Am 2000;44(4):831–850. PMID: 11048275.

29. Am J Orthod Dentofacial Orthop 2006;129(2):266–272. DOI: 10.1016/j.ajodo.2004.03.043

30. Haywood R, Osman Y, Grobler SR. A clinical study of the effectiveness of a light emitting diode system on tooth bleaching. Open Dent J 2012;6:143–147. DOI: 10.2174/187420610601206010143

31. Torres CR, Barcellos DC, Batista GR, et al. Assessment of the effectiveness of light-emitting diode and diode laser hybrid light
31. Domínguez A, García JA, Costela A, et al. Influence of the light source and bleaching gel on the efficacy of the tooth whitening process. Photomed Laser Surg 2011;29(1):53–59. DOI: 10.1089/pho.2009.2751

32. Kossatz S, Dalanhol AP, Cunha T, et al. Effect of light activation on tooth sensitivity after in-office bleaching. Oper Dent 2011;36(3):251–257. DOI: 10.2341/10-289-C

33. Lima DA, Aguiar FH, Liporoni PC, et al. In vitro evaluation of the effectiveness of bleaching agents activated by different light sources. J Prosthodont 2009;18(3):249–254. DOI: 10.1111/j.1532-849X.2008.00420.x

34. Luk K, Tam L, Hubert M. Effect of light energy on peroxide tooth bleaching. J Am Dent Assoc 2004;135(2):194–229. DOI: 10.14219/jada.archive.2004.0151

35. Hein DK, Ploeger BJ, Hartup JK, et al. In-office vital tooth bleaching—what do lights add? Compend Contin Educ Dent 2003;24(4A):340–352. PMID: 11048275.

36. Zhang C, Wang X, Kinoshita J, et al. Effects of KTP laser irradiation, diode laser, and LED on tooth bleaching: a comparative study. Photomed Laser Surg 2007;25(2):91–95. DOI: 10.1089/pho.2006.2025