Journal of
Lasers
in Medical Sciences

J Lasers Med Sci 2017 Autumn;8(4):191-196

Original Article

http://journals.sbmu.ac.ir/jlms

doi 10.15171/jlms.2017.35

In Vitro Effect of Bleaching With 810 nm and 980 nm Diode Laser on Microhardness of Self-cure and Light-Cure Glass Ionomer Cements

Ladan Ranjbar Omrani[1], Sara Khoshamad[2], Elham Tabatabaei Ghomshe[3], Nasim Chiniforush[1], Sedighe Sadat Hashemi Kamangar[1*]

[1]Department of Operative Dentistry, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran,
[2]Tehran University of Medical Sciences, Tehran, Iran
[3]School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran

***Correspondence to**
Dr. Sedighe Sadat Hashemi Kamangar, Associate Professor, Tehran University of medical sciences, Tehran, Iran.
Tel: +98 2155851151;
Fax: +98 2155851149;
Email: smhk58950@gmail.com

Published online 27 September 2017

Abstract

Introduction: This study sought to assess the effect of bleaching combined with irradiation of 810 nm and 980 nm diode laser on microhardness of 2 commonly used self-cure and light-cure glass ionomer cements (GICs) in comparison with conventional bleaching (without laser).

Methods: In this in vitro, experimental study, 60 samples were fabricated of A2 shade of Fuji IX and Fuji II LC GICs (n = 30) and each group was divided into 3 subgroups (n = 10). The first subgroups were subjected to bleaching with Opalescence Xtra Boost plus 980 nm diode laser irradiation. The second subgroups were subjected to bleaching with Opalescence Boost plus 810 nm diode laser irradiation and the third subgroups were subjected to bleaching with Opalescence Xtra Boost without laser. Microhardness was measured at baseline and after the intervention using Vickers hardness tester. The data were analyzed using two-way analysis of variance (ANOVA) ($P < 0.05$).

Results: Microhardness decreased in all subgroups after the intervention ($P < 0.001$) irrespective of the type of GIC ($P = 0.201$) or surface treatment ($P = 0.570$). The baseline microhardness of the three subgroups within each group of GIC was not significantly different ($P = 0.456$), but the baseline microhardness of conventional GIC was significantly higher than that of resin modified GIC ($P = 0.004$).

Conclusion: Bleaching with/without laser irradiation decreases the microhardness of GICs. The baseline microhardness of conventional GIC is higher than that of resin modified GIC.

Keywords: Glass ionomer cements; Hardness; Lasers; Tooth bleaching.

Introduction

In the recent years, tooth bleaching has become increasingly popular due to its optimal efficacy and non-invasive nature. It can be performed in the office or at home by use of over the counter products.[1] This treatment is based on the use of hydrogen peroxide or carbamide peroxide, which release unstable free radicals that react with stains and pigments and result in tooth whitening.[2] Factors such as the concentration of hydrogen peroxide and the source of energy as driving force of chemical reactions can affect the efficacy of bleaching treatment.[3] High-intensity light was first used to enhance the whitening chemical reactions. Thermal lamps and hot spatula were later used as heat source to enhance the whitening reaction. Although effective, these methods carried the risk of pulp hyperthermia.[4] Presently, activating light sources such as plasma arc lamps and laser at different wavelengths have replaced direct heat to enhance the whitening efficacy of bleaching agents.[5] Use of lasers such as diode laser at 810 or 980 nm wavelength and Nd:YAG laser at 1060 nm wavelength is increasing for this purpose due to the optimal efficacy of photothermal bleaching.[6]

On the other hand, there are some concerns regarding the effects of bleaching treatment on dental materials, which are susceptible to wear and degradation.[7] Chemical softening caused by bleaching can potentially affect the physical and mechanical properties of tooth-colored restorative materials such as microhardness and roughness.[8,9] Dental materials may show variable reactions to bleaching agents. These reactions may range from alterations in surface morphology to change in their physical and chemical properties.[1]

Microhardness is defined as resistance of a material to indentation. As one of the most important properties of restorative materials, microhardness is often measured to

Please cite this article as follows: Ranjbar Omrani L, Khoshamad S, Tabatabaei Ghomshe E, Chiniforush N, Hashemi Kamangar SS. In vitro effect of bleaching with 810 nm and 980 nm diode laser on microhardness of self-cure and light-cure glass ionomer cements. *J Lasers Med Sci.* 2017;8(4):191-196. doi:10.15171/jlms.2017.35.

assess the possible negative effects of bleaching products on these materials. However, studies on this topic have often yielded controversial results.[2,3] A previous study reported a reduction in microhardness of glass ionomer cement (GIC) following bleaching[8] while another study reported an increase in microhardness of GIC after bleaching treatment.[10]

In the clinical setting, many dental restorations need to be replaced after bleaching treatment due to the negative effects of bleaching on their physical and chemical properties.[8,11] However, in some cases, as in non-carious cervical erosions, restorations need to be done prior to bleaching treatment in order to prevent tooth hyper-sensitivity.[9]

Since the physical properties of many restorative materials such as GICs change during bleaching treatment, finding cements with higher resistance to degradation due to exposure to bleaching agents is a priority. This study aimed to assess the effect of bleaching with and without laser irradiation on microhardness of 2 commonly used self-cure and light-cure GICs.

Methods

This in vitro, experimental study was conducted on 60 GIC samples fabricated of A2 shade of Fuji IX self-cure and Fuji II LC light-cure GICs. The characteristics of the materials used in this study and the manufacturers are summarized in Table 1. The sample size was calculated to be 10 samples in each subgroup according to a study by Yap and Wattanapayungkul,[9] and assuming $\alpha = 0.05$, $\beta = 00.2$, minimum significant difference of 3 units and standard deviation of 2.85 using Minitab software. The 30 samples fabricated of each GIC were divided into three subgroups. Thus, a total of 6 subgroups ($n = 010$) were evaluated in this study as follows:

1. Fuji IX GIC subjected to bleaching with Opalescence Boost bleaching agent plus 980 nm diode laser irradiation
2. Fuji IX GIC subjected to bleaching with Opalescence Boost bleaching agent plus 810 nm diode laser irradiation
3. Fuji IX GIC subjected to bleaching with Opalescence Boost bleaching agent
4. Fuji II LC subjected to bleaching with Opalescence Boost bleaching agent plus 980 nm diode laser irradiation
5. Fuji II LC subjected to bleaching with Opalescence Boost bleaching agent plus 810 nm diode laser irradiation
6. Fuji II LC subjected to bleaching with Opalescence Boost bleaching agent.

Samples measuring 10 mm in diameter and 1 mm in thickness were fabricated of GICs. In brief, one spoon of Fuji II LC GIC and 2 drops of liquid were placed on a mixing pad. The powder was divided into 2 parts. The first part was gently mixed with the liquid for 20 seconds. The second part was then mixed and the mixture was transferred to a glass mold by a spatula. It was gently condensed by a condenser. A transparent Mylar strip was placed on top of it to ensure a smooth surface. Light curing was performed for 40 seconds using a light curing unit (Optilux, Kerr, Orange, CA, USA) with a light intensity of 400 mW/cm^2. The samples were then removed from the mold and cured for an extra 20 seconds from all 4 aspects to ensure complete polymerization.[12] The light intensity of the device was checked periodically.

For the fabrication of Fuji IX samples, one spoon of powder and one drop of liquid were placed on a mixing pad. The powder was divided into 2 parts. The first part was gently mixed with the liquid for 10 seconds. The remaining powder was added to the mixture and mixed for another 15-20 seconds. The mixture was transferred to a glass mold, a Mylar strip was placed on top of it and light curing was performed as described above. Immediately after setting, varnish was applied on the surface of samples as recommended by the manufacturer.[6]

The samples fabricated of both types of GICs were stored in distilled water at 37°C for 24 hours to ensure complete polymerization. The surface of each sample was finished and polished using medium, fine and super fine polishing burs (Ultradent, South Jordan, UT, USA). The samples were then rinsed with water for one minute and dried.

Baseline microhardness of the samples was then measured using a Vickers hardness tester (Metam, Moscow, Russia). During the study period, the samples were stored in screw-top glass containers containing distilled water at 37°C.[13]

Bleaching was performed using Opalescence Boost (Ultradent Products. South Jordan, UT, USA), which contains 40% hydrogen peroxide, according to the

Table 1. Characteristics of the Materials Used in This Study

Material	Type	Mixing Time (s)	Working Time (s)	Setting Time (s)	Batch No.	Powder/Liquid Ratio	Manufacturer
Fuji IX	Conventional GIC	10	120	360	002578	1/1	GC International, Tokyo, Japan
Fuji II LC	Resin modified GIC	20-25	195	20	003254	1/2	GC International, Tokyo, Japan
Opalescence Boost (40%)	In-office bleaching agent	-	-	-		-	Ultradent products, South Jordan, UT, USA

Abbreviation: GIC, glass ionomer cement.

manufacturer's instructions at room temperature. In the control group, bleaching agent was applied in 1.5 mm thickness on the surface of samples and remained for 20 minutes. After removal of the bleaching agent, the samples were thoroughly rinsed with water.

In 980 nm laser subgroups, the bleaching agent was applied on the samples in 1.5 mm thickness and irradiated with Doctor Smile Wiser Laser (Lambda Spa, Brendola (VI), Italy) with La3D0001.3 code, 980 nm wavelength, 1.5 W power, continuous mode and II B/4 class for 30 seconds. Irradiation was done in triplicate with one minute intervals. The samples were allowed 5 minutes and then the bleaching agent was removed and the samples were rinsed with distilled water for 30 seconds.

In 810 nm laser subgroups, the bleaching agent was applied on the samples in 1.5 mm thickness and irradiated with Gigga Laser (Gigga, Wuhan, China) with GBOX-15 AB code, 810 nm wavelength, 1.5 W power, continuous mode and II B/4 class for 30 seconds. The rest of the procedure was continued as explained above.

After each bleaching process, microhardness was measured at three randomly selected points on each sample surface using Vickers microhardness tester (Metam, Moscow, Russia). These points were not at the margins or areas with visible irregularity. The conical diamond indenter applied 200g load at 136° angle to the surface for 15 seconds. The indent created on the surface was square-shaped. The diameters of the square were immediately measured under a stereomicroscope and the microhardness number (VH) was calculated using the formula below:

$VH=1.845pd^2$

Where p is the applied load in kg and d is the mean diameter of square-shaped indent in mm. Three square-shaped indents were created on the surface of each sample and the mean value was calculated.

The data were analyzed using SPSS version 18 (SPSS Inc., IL, USA). The mean, standard deviation and change in microhardness after the intervention were calculated and reported based on the type of surface treatment, type of laser and type of GIC. Two-way analysis of variance (ANOVA) was used to assess the effect of type of GIC and surface treatment and their interaction effect on microhardness. Level of significance was set at $P<0.05$.

Results

At baseline, conventional GIC showed higher microhardness values. After bleaching, maximum microhardness was noted in Fuji IX conventional GIC subjected to bleaching alone (control). Minimum microhardness value was noted in Fuji II LC GIC subjected to bleaching plus 810 nm diode laser irradiation. The mean and standard deviation of microhardness at baseline and after the intervention are presented in Table 2.

The results showed that microhardness decreased in all groups after the intervention ($P<0.001$) irrespective of the type of glass ionomer ($P=0.201$) or surface treatment ($P=0.570$). In other words, type of glass ionomer and surface treatment had no significant effect on microhardness ($P>0.05$). The baseline microhardness was not significantly different among the subgroups in each GIC group ($P=0.456$). However, the baseline microhardness of Fuji IX conventional GIC was significantly higher than that of Fuji II LC resin modified GIC ($P=0.004$). The trend of change in microhardness in the subgroups is shown in Figure 1.

Discussion

Patients' high demand for esthetic dental treatments has resulted in increasing popularity of tooth bleaching methods. In-office tooth bleaching has the advantage of immediate effect and does not often require a second visit to the office. However, some concerns exist regarding the effect of bleaching agents on tooth-colored restorative materials such as GICs.[14]

The effect of bleaching on properties of some restorative materials has been previously evaluated.[15] Thus, this study assessed the effect of a bleaching agent on microhardness

Table 2. The Mean and Standard Deviation of Microhardness (MPa) at Baseline and After the Intervention in the Subgroups (n = 10)

Group			Minimum	Maximum	Mean	SD
Control	Fuji II LC	Baseline	50.73	79.80	59.8200	8.05243
		Post intervention	9.53	64.53	45.9100	15.42341
	Fuji IX	Baseline	50.37	82.36	66.7760	11.95061
		Post intervention	37.16	80.30	57.0060	12.55374
810 nm laser	Fuji II LC	Baseline	50.73	72.73	59.9200	7.02452
		Post intervention	37.70	61.10	48.4180	8.36789
	Fuji IX	Baseline	50.37	80.63	64.7760	10.65621
		Post intervention	10.76	127.33	53.4900	29.92043
980 nm laser	Fuji II LC	Baseline	48.06	87.63	62.4200	11.72744
		Post intervention	25.70	82.53	44.7940	14.39160
	Fuji IX	Baseline	50.37	82.36	63.7760	11.85146
		Post intervention	21.80	78.66	53.3870	20.72847

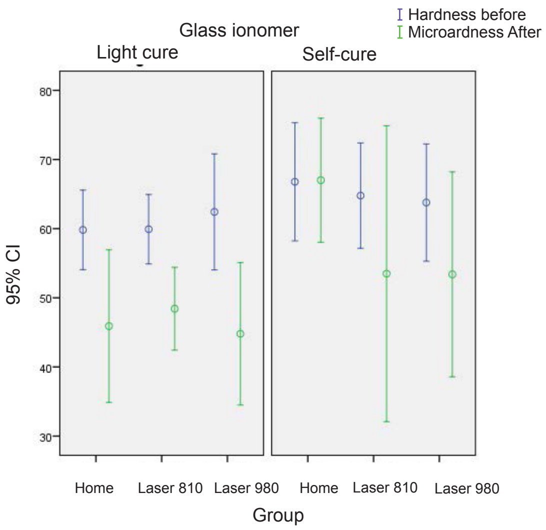

Figure 1. The Trend of Change in Microhardness in the Subgroups.

of a conventional (Fuji IX) and a resin modified (Fuji II LC) GIC.

Opalescence Boost, which is often used for in-office bleaching was used as the bleaching agent in this study. It is supplied in the form of a syringe containing 2 substances, which are mixed before application, producing 40% hydrogen peroxide and carotene pigment. Carotene is an orange pigment found in carrot and vegetables, which can convert the standard blue light of light curing units to thermal energy.[9] Hydrogen peroxide can form several types of reactive oxygen species depending on temperature, pH, light source, CO catalyst and presence of metal ions. Hydrogen peroxide is an oxidizing agent, which can produce free HO2- and O-radicals that are highly reactive and can break down the macromolecules of pigments into small molecules. Also, in inorganic structures such as protein matrix, free radicals bond to stain molecules. At the end of reaction, free radicals form oxygen molecules in water.[16]

In the current study, diode laser with 1.5 W power was used to activate the bleaching agent. It has infrared wavelength and a photothermal effect. The bleaching agent must have pigments to absorb laser energy; carotene serves this purpose in Opalescence Boost. According to the manufacturer, this bleaching agent does not require an activator. However, evidence shows that diode laser irradiation of Opalescence Boost results in higher whitening efficacy in a shorter time.[17,18] It should be noted that laser irradiation enhances the release of hydroxyl radicals. Moreover, it increases the penetration depth of bleaching agent and enhances the efficacy of bleaching.[17,18] Due to limitations in heat production considering possible damage to dental pulp by over-heating, diode laser in safe range of 810-980 nm wavelength was used in this study. At this wavelength, laser is well absorbed by aqueous solutions and quickly increases the temperature of bleaching agent; risk of pulp injury due to over-heating is minimized as such.[19,20]

Hardness is defined as resistance of a material to indentation or perforation. Chemical softening due to bleaching can affect the durability and clinical service of dental restorations.[5] The current results showed a reduction in microhardness of all subgroups after bleaching. Maximum microhardness was noted in Fuji IX subjected to bleaching alone (control) and minimum microhardness was recorded in Fuji II LC subjected to bleaching plus 810 nm diode laser. Also, Fuji IX conventional GIC had significantly higher microhardness than resin modified GIC both before bleaching. Similarly, Xie et al[21] in 2000 reported higher Knoop hardness of conventional GIC than that of resin modified GIC. They explained this finding to be due to the compact surface texture containing hard glass particles packed in the matrix as well as the presence of lower amounts of carboxylic acid in its formulation. In contrast, Kanchanavasita et al[22] in 1998 reported higher primary microhardness of resin modified GIC compared to conventional GIC and discussed that addition of resin to GIC enhanced its mechanical properties compared to those of conventional GIC.

The pH of the bleaching agent used in our study was 6.53; at this pH, the bleaching agent can cause erosion of GIC surface.[14] The suggested mechanism of erosion of GIC is as follows: In acidic solutions, hydrogen ions replace cationic metal ions in the structure of GIC and form cross links with poly carboxylic acid molecules. According to the concentration gradient, cationic metal ions are released from the surface and their concentration in cement matrix decreases. Glass particles are subsequently released from the surface and as the glass network disintegrates, glass particles are covered with silanol (-SiOH) groups. Simultaneous attack with H+ and F- ions disintegrates the Si-O-Si bonds in the glass network.[10] Surface damage occurs as such following the application of bleaching agent on conventional GIC. This damage can be permanent (due to failure of primary bonds within the material) or reversible following softening and plasticization of material surface (due to failure of secondary bonds). Permanent damage occurs due to wash out of ions.[23]

In resin modified GICs, bleaching agent can cause chemical softening of resin matrix. Free radicals soften resin polymers and decrease their solubility coefficient from 2.97×10^4 J/m^3 to 1.82×10^4 J/m^3.[9,16]

The mechanism of reduction of microhardness of resin modified GICs due to bleaching is as follows: Insoluble fillers release ions such as silicon, barium, strontium and fluoride into the bleaching agent and distilled water. This process creates voids on the GIC surface. Due to osmotic pressure, water is accumulated in voids. Following increase in osmotic pressure, diameter of voids within the material structure increases, which leads to softening and decreases hardness.[24]

Mujdeci and Gokay[25] in 2006 evaluated the effect of bleaching agent on microhardness of tooth-colored restorative materials and reported that bleaching did not decrease the microhardness of GIC, which was in oppose with our findings. They stated that seven days after the setting of GICs, bleaching agents can no longer cause detectable surface degradation in the cement. Yap and Wattanapayungkul[9] in 2002 assessed the effect of in-office bleaching on microhardness of tooth-colored restorations and found no reduction in microhardness due to bleaching, which was different from our results. In their study, bleaching was performed seven days after completion of setting of GIC. This time period results in more complete polymerization of cement and less susceptibility to bleaching.

Similar to our findings, Campos et al[26] in 2002 evaluated the effect of bleaching with carbamide peroxide gel on microhardness of restorative materials and found that bleaching gels containing 10%-15% carbamide peroxide decreased the microhardness of hybrid ionomer. Turker and Biskin[14] in 2003 evaluated the effects of three bleaching agents on composite, compomer and resin modified GIC and reported that resin modified GIC required replacement after bleaching because its surface properties such as surface roughness were significantly deteriorated after bleaching. Another study discussed that a secondary setting results in formation of silicate hydrate phases in conventional GICs, which are mainly responsible for hardness. This does not occur in resin modified GICs because fast setting of light cure GICs, referred to as snap set, postpones the acid-base reactions responsible for the formation of silicate hydrate phases. Thus, the latter is more susceptible to degradation.[27] Turker and Biskin[10] in 2002 reported an increase in microhardness of GICs after bleaching and attributed this increase to accumulation of silica cores on the GIC surface after bleaching and erosion of cement and movement of indenter of Vickers hardness tester on these cores.

The results of the current study showed no significant difference in microhardness among the laser-bleached subgroups of each of the conventional and resin modified GICs. Diode lasers with power more than 3 W are harmful for dental pulp. However, in the 1-2 W range they can be the best lasers for bleaching.[28] Lasers accelerate the bleaching process and decrease the time of procedure. On the other hand, the effect of bleaching is directly related to the exposure time.[28] Thus, in our study, the effect of bleaching alone (with longer exposure time) was similar to diode laser-bleached subgroups (with shorter exposure time) despite of the results of previous studies that showed reduction of enamel hardness following diode laser-activated bleaching.[28,29] Future studies are required to assess the effect of diode laser irradiation on other properties of GICs. Also, effect of laser bleaching on microhardness of GICs, enamel and dentin must be compared in future studies.

Conclusion

Based on the results of this study, bleaching with/without laser decreases the microhardness of GICs. This reduction was greater in resin modified GIC compared to the conventional GIC. Changing the diode laser wavelength did not change the effect of bleaching agent on microhardness of GICs.

Conflict of Interests

The authors declare no conflict of interest.

References

1. Heymann HO. Tooth whitening: facts and fallacies. *Br Dent J*. 2005;198(8):514. doi:10.1038/sj.bdj.4812298
2. Kwon SR, Wertz PW. Review of the mechanism of tooth whitening. *J Esthet Restor Dent*. 2015;27(5):240-257. doi:10.1111/jerd.12152.
3. Jordan RE, Boksman L. Conservative vital bleaching treatment of discolored dentition. *Compend Contin Educ Dent*. 1984;5(10):803-805.
4. Sun G. The role of lasers in cosmetic dentistry. *Dent Clin North Am*. 2000;44(4):831-850.
5. Buchalla W, Attin T. External bleaching therapy with activation by heat, light or laser--a systematic review. *Dent Mater*. 2007;23(5):586-596. doi:10.1016/j.dental.2006.03.018.
6. Garber DA. Dentist-monitored bleaching: a discussion of combination and laser bleaching. *J Am Dent Assoc*. 1997;128 Suppl:26s-30s.
7. Haywood VB, Heymann HO. Nightguard vital bleaching: how safe is it? *Quintessence Int*. 1991;22(7):515-523.
8. Taher NM. The effect of bleaching agents on the surface hardness of tooth colored restorative materials. *J Contemp Dent Pract*. 2005;6(2):18-26.
9. Yap AU, Wattanapayungkul P. Effects of in-office tooth whiteners on hardness of tooth-colored restoratives. *Oper Dent*. 2002;27(2):137-141.
10. Turker SB, Biskin T. The effect of bleaching agents on the microhardness of dental aesthetic restorative materials. *J Oral Rehabil*. 2002;29(7):657-661.
11. Attin T, Hannig C, Wiegand A, Attin R. Effect of bleaching on restorative materials and restorations--a systematic review. *Dent Mater*. 2004;20(9):852-861. doi:10.1016/j.dental.2004.04.002.
12. Hubbezoglu I, Akaoglu B, Dogan A, et al. Effect of bleaching on color change and refractive index of dental composite resins. *Dent Mater J*. 2008;27(1):105-116.
13. AL-Jubori SH. The Effect of Bleaching on the Color Stability and Microhardness of Tooth-Colored Restorative Materials. *Al-Rafidain Dent J*. 2014:13(2):181-191.
14. Turker SB, Biskin T. Effect of three bleaching agents on the surface properties of three different esthetic restorative materials. *J Prosthet Dent*. 2003;89(5):466-473. doi:10.1016/s0022391303001057.
15. Shim YS. Effect of in-office bleaching application on the color, microhardness and surface roughness of five esthetic restorative materials. *Indian J Sci Technol*. 2015;8(S1):420-425.
16. Polydorou O, Mönting JS, Hellwig E, Auschill TM. Effect of in-office tooth bleaching on the microhardness of six dental esthetic restorative materials. *Dent Mater*. 2007;23(2):153-158. doi: 10.1016/j.dental.2006.01.004.

17. Li Q, Yu H, Wang Y. Colour and surface analysis of carbamide peroxide bleaching effects on the dental restorative materials in situ. *J Dent.* 2009;37(5):348-356. doi:10.1016/j.jdent.2009.01.003.
18. Gurgan S, Cakir FY, Yazici E. Different light-activated in-office bleaching systems: a clinical evaluation. *Lasers Med Sci*. 2010;25(6):817-822. doi:10.1007/s10103-009-0688-x.
19. Goharkhay K, Schoop U, Wernisch J, Hartl S, De Moor R, Moritz A. Frequency doubled neodymium:yttrium-aluminum-garnet and diode laser-activated power bleaching--pH, environmental scanning electron microscopy, and colorimetric in vitro evaluations. *Lasers Med Sci.* 2009;24(3):339-346. doi:10.1007/s10103-008-0567-x.
20. Dostalova T, Jelinkova H, Housova D, et al. Diode laser-activated bleaching. *Braz Dent J*. 2004;15:SI-3.
21. Xie D, Brantley WA, Culbertson BM, Wang G. Mechanical properties and microstructures of glass-ionomer cements. *Dent Mater.* 2000;16(2):129-138.
22. Kanchanavasita W, Anstice HM, Pearson GJ. Long-term surface micro-hardness of resin-modified glass ionomers. *J Dent*. 1998;26(8):707-712.
23. Mair L, Joiner A. The measurement of degradation and wear of three glass ionomers following peroxide bleaching. *J Dent*. 2004;32 Suppl 1:41-45.
24. Lee JH, Kim HI, Kim KH, Kwon YH. Effect of bleaching agents on the fluoride release and microhardness of dental materials. *J Biomed Mater Res.* 2002;63(5):535-541. doi:10.1002/jbm.10311.
25. Mujdeci A, Gokay O. Effect of bleaching agents on the microhardness of tooth-colored restorative materials. *J Prosthet Dent*. 2006;95(4):286-289. doi:10.1016/j.prosdent.2006.01.010.
26. Campos I, Briso AL, Pimenta LA, Ambrosano G. Effects of bleaching with carbamide peroxide gels on microhardness of restoration materials. *J Esthet Restor Dent.* 2003;15(3):175-182.
27. Momoi Y, Hirosaki K, Kohno A, McCabe JF. In vitro toothbrush-dentifrice abrasion of resin-modified glass ionomers. *Dent Mater.* 1997;13(2):82-88.
28. Nematianaraki S, Fekrazad R, Naghibi N, Kalhori KA, Junior AB. Effects of the bleaching procedures on enamel micro-hardness: Plasma Arc and diode laser comparison. *Laser Ther.* 2015;24(3):173-177. doi:10.5978/islsm.15-OR-10.
29. Ghanbarzadeh M, Ahrari F, Akbari M, Hamzei H. Microhardness of demineralized enamel following home bleaching and laser-assisted in office bleaching. *J Clin Exp Dent.* 2015;7(3):e405-409. doi:10.4317/jced.51705.