Photodiagnosis and Photodynamic Therapy 31 (2020) 101952

Contents lists available at ScienceDirect

Photodiagnosis and Photodynamic Therapy

journal homepage: www.elsevier.com/locate/pdpdt

The effect of laser-activated bleaching with 445 nm and 915 nm diode lasers on enamel micro-hardness; an in vitro study

Sogol Saberi[a], Mahboubeh Rouzsaz[b,*], Farhad Shafie[c], Sadra Einizadeh[b], Mohammad Javad Kharazifard[d], Sima Shahabi[e,*]

[a] Laser Research Center, Dentistry Research Institute, Tehran University of Medical Sciences, Tehran, Iran
[b] Tehran University of Medical Sciences, Tehran, Iran
[c] Department of Dental Biomaterials, Tehran University of Medical Sciences, Tehran, Iran
[d] Dental Research Center, Tehran University of Medical Sciences, Tehran, Iran
[e] Department of Dental Biomaterials, Tehran University of Medical Sciences, Tehran, Iran

ARTICLE INFO

Keywords:
Tooth bleaching
Diode laser
Hardness
Dental Enamel

ABSTRACT

Background: The appearance of the teeth is of great importance to patients, particularly tooth color. In recent years, tooth whitening has been one of the most popular ways to restore tooth color. Bleaching gels can be affected by heat, light or laser, which can improve its effects. This study intends to examine the effects of two different wavelengths of diode laser (445 & 915 nm) after the bleaching process, on the enamel micro-hardness.
Methods: A total of 65 caries-free humans third molars were randomly divided into five groups (N = 13): first group: bleaching gel activated with 915 nm diode laser (1.5 W), second: bleaching gel activated with 915-nm (2.5 W), third: bleaching gel activated with 445-nm (1 W), fourth: bleaching gel activated with 445-nm (1.5 W), fifth (control group): bleaching gel without laser activation. Micro-hardness test (Vickers test) was performed before and after the treatment. The data were submitted to repeated measurement ANOVA and Tukey's HSD post hoc test ($\alpha = 0.05$).
Results: Enamel micro-hardness did not change significantly in groups 3 and 4 but decreased in groups 1 and 2. Group 2 showed the most reduction in micro-hardness. There were no significant changes in the control group.
Conclusion: According to the results of this study, 445 nm Diode laser did not reduce enamel micro-hardness, making it suitable for bleaching treatments. However, more studies are required to consider other factors, such as color changes and pulp temperature.

1. Introduction

Tooth whitening is one of the most popular ways to restore and improve tooth color, and tooth bleaching methods have received a lot of attention in recent years (1).

During the bleaching process, hydrogen peroxide acts as a strong oxidizing agent that converts to free radicals (2). These radicals attack and break down the pigment molecules within the tooth, which cause tooth discolouration and eventually whiten the tooth (3).

Tooth whitening agents can be affected by heat, light, or lasers, which increase the temperature of the bleaching agent (4). Thus accelerating the conversion of hydrogen peroxide to free radicals (5), and causing the pigmented carbon chains to separate more quickly (6). Eventually, this procedure reduces total in-office chair time and accelerates the bleaching gel's action by energizing hydrogen peroxide through the use of various light sources (3).

Laser energy can cause physicochemical changes in tooth enamel, which is affected by crystalline changes in the hydroxyapatite crystal and the elimination of carbonate content in the inter-crystalline areas. Such changes also protect against harmful effects due to the widespread penetration of hydroxyapatite. Besides, laser bleaching has caused significantly lesser sensitivity compared to conventional in-office bleaching (7).

Previous studies reported that Light activation of the bleaching gel with hybrid LED sources was more effective than the control group. Also, power bleaching provided faster and more intense bleaching than bleaching gel without light activation (8).

Besides, some articles reported that color changes in power bleaching were much better than bleaching gel without light activation (9–11).

* Corresponding authors at: Department of Dental Biomaterials, School of dentistry, Tehran University of Medical Sciences, Tehran, Iran.
E-mail addresses: mahboobehroozsaz@gmail.com (M. Rouzsaz), shahabis@sina.tums.ac.ir (S. Shahabi).

https://doi.org/10.1016/j.pdpdt.2020.101952
Received 28 May 2020; Received in revised form 1 August 2020; Accepted 3 August 2020
Available online 18 August 2020
1572-1000/

Teeth whitening process involves the use of whitening gel on the tooth surface for a long time, which may have harmful effects such as changes in enamel micro-hardness and an increase in surface roughness (12,13).

According to recent studies, micro-hardness was reduced during bleaching and free radical activities (14). Various studies have been performed to investigate micro-hardness changes in light-activated bleaching (14–16).

Over the years, the effects of various lasers, more recently, including diode lasers, have been studied on dental treatments (17). The wavelengths of 445 nm and 915 nm are known to be relatively new and have been present in a few articles (18–22). FDA has approved the wavelength of 445 nm, so the results are useful on the teeth (FDA: K180044). Researchers have evaluated the healing power of 915 nm diode laser in the oral cavity (21) and the effect of light-activated (Diode 915 nm laser) bleaching on enamel and pulp chamber temperature increase (23,24). Also, artificial caries resistance in enamel with topical Fluoride activated by 445 nm diode laser has been studied (25). However, so far, these wavelengths have not been considered in bleaching treatments.

Recently, lasers with a spectral wavelength in the blue region of 445 nm or 532 nm have been developed (17). Blue lasers have shorter wavelengths and higher absorption in pigments, hemoglobin and melanin (26). So they penetrate shallowly into the tissue and do not disperse. It is one of the most critical advantages of them. As a result, the risk of accidental damage in the deeper layers is reduced due to the shallow penetration. In addition, less energy absorption occurs in the environment, and an increase in the temperature of the surrounding tissue does not occur as a side effect (27). This feature is vital due to the absorption of the 445 nm laser in the bleaching gel pigments, and an increase in gel temperature. Also, less penetration and scattering happens. However, the laser penetrates the hard tissue of the enamel less and does not appear to affect the micro-hardness of the enamel. Due to the effective results of LED light in the blue spectrum and the similarity of the wavelengths, as well as the advantages of lasers, this spectrum of wavelengths has been considered.

This study aimed to investigate the effect of a 445 nm (1 w and 1.5 w) and 915 nm (1.5 w and 2.5 w) diode laser after the bleaching process on the micro-hardness of human tooth enamel.

2. Materials and methods

According to the results of Magalhaes (28) and using One-Way ANOVA analysis, SPSS ll software with $\alpha = 0.05$, $\beta = 0.2$, Effect size = 0.49 and mean standard deviation of 18.8; minimum sample size required for each of the five groups was 13.

Thirty-three human third molars have recently been extracted due to periodontal and orthodontic problems, immersed in a 0.2% thymol solution. The samples were selected to be free of caries, hypo-calcification points and cracks. Then they were cut by high-speed disk, first from the DEJ area, and were cut in half in mesio-distal direction. Therefore, the total number of samples increased to 65 pieces.

The samples were mounted on acrylic resin with dimensions of 4 x 3 cm and a height of 1 cm by standard micro-hardness test frame. The enamel surface was polished with 800, 1000 and 1200 sandpaper, and it was immersed in physiological serum before, during and after the experiment. They were randomly coded, and their initial micro-hardness were measured and recorded three times, in the center, 1 mm to the right, and 1 mm to the left of the center by entering 15 g of force by Vickers micro-hardness tester (Leitz Miniload2 Microhardness Tester, Leitz, Germany). Then they were randomly divided into five groups (n = 13).

It is recommended to use 1-2 watts of power for diode laser and not above 3 watts of power, to avoid overheating of the pulp chamber (29).

First group: Bleaching gel was applied to the samples and then continuous irradiation of 915 nm diode laser (88dent- pocket laser, Italy) with 1.5 W of power for 30 seconds with a handpiece (multi-tip 8 mm) was performed. The laser radiation process was performed three times. One minute of rest was taken between irradiations. Then the gel was left on the samples for 15 minutes.

Second group: Bleaching gel was applied to the samples and then continuous irradiation of 915 nm diode laser (88dent- pocket laser, Italy) 2.5 W for 30 seconds with handpiece (multi-tip 8 mm) was performed. The laser radiation process was performed three times, and 1 minute of rest was taken between irradiations. Then the gel was left on the samples for 15 minutes.

Third group: Bleaching gel was applied to the samples and then continuous irradiation of 445 nm diode laser (Siroblue laser, dentsply Sirona, Germany) with 1 W of power for 30 seconds with handpiece (multi-tip 8 mm) was performed. The laser radiation process was performed three times, and 1 minute of rest was taken between irradiations. Then the gel was left on the samples for 15 minutes.

Fourth group: Bleaching gel was applied to the samples and then continuous irradiation of 445 nm diode laser (Siroblue laser, dentsply Sirona, Germany) 1.5 W for 30 seconds with handpiece (multi-tip 8 mm) was performed. The laser radiation process was performed three times, and 1 minute of rest was taken between irradiations. Then the gel was left on the samples for 15 minutes.

Fifth group (control): Bleaching gel was applied for 20 minutes with no laser activation.

All samples were carefully washed by water and immersed in physiological serum immediately after treatment with the mentioned protocol.

The same bleaching gel (Boost, chemical activation-H2O2 40%-Ultradent- Opalescence, USA) was used for all groups.

(According to the manufacturer's instructions, the bleaching gel should not remain on the teeth for more than 20 minutes).

After the treatments, the final micro-hardness was measured for all samples.

The collected data were analyzed by repeated measurement ANOVA and Tukey's HSD post hoc test using SPSS Statistics software.

3. Results

In this study, we tried to determine the relationship between diode laser radiation with wavelengths of 915 nm (1.5 W and 2.5 W) and 445 nm (1 W and 1.5 W), and the effects on the human enamel micro-hardness. The initial and final average hardness of study groups are shown in Fig. 1.

Repeated measurement ANOVA showed that there is a significant difference between groups ($p = 0.000$). Tukey's HSD follow up test indicated that laser radiation with a wavelength of 915 nm significantly reduces the micro-hardness of the enamel ($p = 0.000$). Micro-hardness reduction in group 2 (915 nm, 2.5 W) was more than group 1 (915 nm, 1.5 W). Although laser radiation with a wavelength of 445 nm in groups

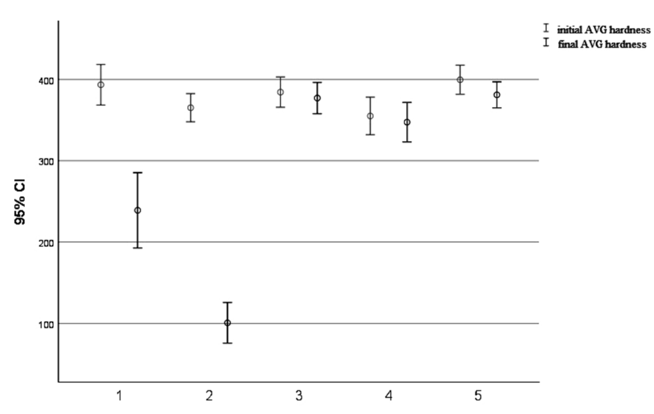

Fig. 1. Mean microhardness change of groups before and after treatment.

Table 1
Significance coefficient of the treated groups

Group	N	Subset for alpha = 0.05		
		1	2	3
2	13	−264.4429		
1	13		−154.3810	
5	13			−18.5238
4	13			−7.6410
3	13			−7.3095
Sig.		1.000	1.000	0.986

Means for groups in homogeneous subsets are displayed.

3, 4, and the control group reduced enamel micro-hardness but did not significantly differ ($p > 0.05$). The homogeneous subsets are presented in Table 1.

4. Discussion

The results are based on the treatment protocol used, which is a combination of studies and recommendations of manufacturers of the product. According to the results, the diode laser radiation of 445 nm did not considerably change the enamel's micro-hardness. However, the wavelength of 915 nm significantly changed the micro-hardness of enamel and increasing laser power was directly related to reducing micro-hardness.

Tooth whitening process involves the use of whitening gel on the tooth surface for a long time, which may have harmful effects such as 1) Sensitivity due to increased enamel porosity (allows the whitening gel to spread into the dentin and pulp through dentin tubes) 2) gingivitis 3) damage to the throat and stomach (12) 4) changes in the micro-hardness of enamel and increase in surface roughness (13).

There are concerns about the changes in enamel micro-hardness because of its importance for maintaining dental health and durability against chewing, and mechanical and chemical forces (30). Several studies reported considerable changes in enamel micro-hardness (14,15,31,32), some of them return to normal micro-hardness after one to two weeks in artificial saliva (15,32) and some articles have not reported considerable differences in the micro-hardness of enamel (33,34).

The majority of studies have shown a reduction in enamel micro-hardness during the use of a high concentration of bleaching gel similar to the office bleaching (14,15,31,32). In our case, bleaching gel was used for a maximum of 20 minutes at a time, which seems to be the most significant difference from the recent studies on the bleaching gel protocols.

With the development of lasers and other light sources used to activate bleaching agents (4), the adverse effects of these sources on tooth hardness have not been reported. There are doubts about the role of these sources in increasing efficiency without damaging the structure of the tooth (35). In recent years, numerous researchers have examined the relationship between the radiation of laser types and the effects on oral tissues, including soft tissue and hard tissue (36,37).

Some researches evaluated enamel and pulp chamber temperature increase after laser radiation. De Moor reviewed numerous light sources, including 915 nm Diode laser and their effects after bleaching treatment. This study showed a rise in temperature at 1.5 W and 3 W above the critical temperature (24). Kivanç showed diode laser (915 nm) activation during vital bleaching induces pulp chamber temperature increase, which may cause thermal tissue damage (23). Sulieman showed, the rise in pulp chamber temperature, with the laser used at 1-2W, was below the critical temperature thought to produce irreversible pulpal damage (5.5 °C). However, a power setting of 3 W induced a pulp chamber temperature increase above this threshold (16 °C); therefore, caution is advised while using this setting (29).

We wanted to have the same power settings in both lasers, and 13 samples piloted with 445 nm and 2.5 W laser. However, due to the burning of bleaching gel during the laser radiation, 2.5 W power setting was replaced with 1 W in this laser.

Zhang et al., Compared KTP (532 nm) and diode laser (980 nm) and LED in the bleaching process, Micro-hardness did not change significantly in any of the three groups of light sources (38). A study by Marcondes et al. aimed to create a specific protocol for Nd: YAG Laser, micro-hardness of Nd: YAG laser-irradiated groups, and halogen light was no different from the control group which had not received any treatment (39). De Magalhaes showed bleaching gel activated with 830 nm diode laser did not change enamel micro-hardness significantly (28). Dionysopoulos et al. used Er, Cr: YSGG laser in the bleaching process. Bleaching groups with and without the laser treatment showed a 10 percent reduction in the micro-hardness (31). In a study by Parreiras et al., In both groups, treated with 35% H_2O_2 bleaching gel, and administered by 35% H_2O_2 bleaching gel with LED light activation, no significant change in enamel micro-hardness was observed (15). Araujo et al. compared LED light sources, argon laser and halogen light. In this comparison, micro-hardness did not show any significant changes (33). In research by Klaric et al., which used ZOOM2, LED405, OLED light sources for bleaching activation, a substantial decrease in microhardness was observed in all groups before activation with light sources. Moreover, after light activation, micro-hardness change was insignificant compare to the previous one(14). Nematianaraki et al. reported enamel micro-hardness reduction after bleaching gel activation with both plasma arc (350-700 nm) and diode laser (810 nm) groups (16). Mondelli et al. reported that dental bleaching with different protocols (15%, 25% and 35% HP) with or without laser activation (hybrid light) reduces dental micro-hardness (40). Ghanbarzadeh et al., compared home bleaching (carbamide peroxide 15%) with laser-assisted office bleaching (hydrogen peroxide 40% + gallium-aluminum-arsenide (GaAlAs) diode laser (810 nm)) on white spot lesions, enamel micro-hardness decreased in both groups (41).

Despite the multiplicity of researches, there is still no agreement on a specific protocol for laser radiation during bleaching treatment, whereas laser devices are used in dental clinics. Also, it is challenging to compare different lasers due to the difference in radiant power and wavelengths of lasers. Some types of lasers for bleaching treatment have not been studied yet.

Over the years, the use of LED lighting during the bleaching process has been prevalent, and the results have been satisfactory. This light is in the blue spectrum, and many studies have been done on its effectiveness (42). So it is essential to check lasers with a spectral wavelength in the blue region.

The high penetration depth of 915 nm laser in hard tissue and less absorption in pigment (26,43,44) seems to have less effect on bleaching gel and more penetration into the enamel. Thus, the more destructive impact on enamel structure.

5. Conclusion

According to the results of our study, diode laser with a wavelength of 445nm reduces the microharness of enamel less than 915nm laser after laser assisted tooth whitening. However, more studies are required to evaluate other features of tooth structure.. The obtained results were according to the treatment protocol used, which is a combination of studies and the manufacturers' recommendations. More studies are required to develop a specific protocol for using diode 445 nm laser to activate bleaching agents.

Acknowledgment

The authors declare no potential conflicts of interest concerning the publication of this study. This article was supported by the Tehran University of Medical Sciences & Health Services, Tehran, IRAN(grant 98-02-69-42942).

References

[1] K.M. Nazanin, The bleaching of teeth: a review of the literature, Journal of dentistry 34 (2016) 412–419.
[2] C. Fornaini, G. Lagori, E. Merigo, M. Meleti, M. Manfredi, R. Guidotti, A. Serraj, P. Vescovi, Analysis of shade, temperature and hydrogen peroxide concentration during dental bleaching: in vitro study with the KTP and diode lasers, Lasers in medical science. 28 (January (1)) (2013) 1–6.
[3] K. Baroudi, N.A. Hassan, The effect of light-activation sources on tooth bleaching, Nigerian medical journal: journal of the Nigeria Medical Association 55 (September (5)) (2014) 363.
[4] K. Luk, L. Tam, M. Hubert, Effect of light energy on peroxide tooth bleaching, The Journal of the American Dental Association. 135 (February (2)) (2004) 194–201.
[5] T. Dostalova, H. Jelinkova, D. Housova, et al., Diode laser-activated bleaching, Brazilian dental journal 15 (2004) SI-3.
[6] R.J. Jain, S.K. Jadhav, V.S. Hegde, Effects of conventional and laser-activated intracoronal bleaching agents on ultrastructure and mineral content of dentin, Journal of Dental Lasers 7 (2013) 2–8.
[7] M.A. Mathews, R.M. Mariam, S. Sudeep, N. Dinesh, Clinical evaluation of laser bleaching vs. conventional in-office bleaching, Journal of Dental Lasers. 7 (July (2)) (2013) 54.
[8] C.R. Torres, D.C. Barcellos, G.R. Batista, A.B. Borges, K.V. Cassiano, C.R. Pucci, Assessment of the effectiveness of light-emitting diode and diode laser hybrid light sources to intensify dental bleaching treatment, Acta Odontologica Scandinavica. 69 (May (3)) (2011) 176–181.
[9] A. Dominguez, J.A. Garcia, A. Costela, C. Gomez, Influence of the light source and bleaching gel on the efficacy of the tooth whitening process, Photomedicine and laser surgery 29 (January (1)) (2011) 53–59.
[10] S. Liang, Y. Sa, T. Jiang, X. Ma, W. Xing, Z. Wang, Y. Wang, In vitro evaluation of halogen light-activated vs chemically activated in-office bleaching systems, Acta Odontologica Scandinavica. 71 (September (5)) (2013) 1149–1155.
[11] S. Kossatz, A.P. Dalanhol, T. Cunha, A. Loguercio, A. Reis, Effect of light activation on tooth sensitivity after in-office bleaching, Operative Dentistry. 36 (May (3)) (2011) 251–257.
[12] M.A. Al-Maliky, M. Frentzen, J. Meister, Artificial Caries Resistance in Enamel after Topical Fluoride Treatment and 445 nm Laser Irradiation, BioMed research international 2019 (2019).
[13] I. Katalinić, A. Budimir, Z. Bošnjak, S. Jakovljević, I. Anić, The photo-activated and photo-thermal effect of the 445/970 nm diode laser on the mixed biofilm inside root canals of human teeth in vitro: A pilot study, Photodiagnosis and photodynamic therapy 26 (June) (2019) 277–283.
[14] E. Klaric, M. Rakic, I. Sever, O. Milat, M. Par, Z. Tarle, Enamel and Dentin Microhardness and Chemical Composition After Experimental Light-activated Bleaching, Operative dentistry 40 (4) (2015) E132–41.
[15] S.O. Parreiras, P. Vianna, S. Kossatz, A.D. Loguercio, A. Reis, Effects of light activated in-office bleaching on permeability, micro-hardness, and mineral content of enamel, Operative dentistry. 39 (5) (2014) E225–30.
[16] S. Nematianaraki, R. Fekrazad, N. Naghibi, K.A. Kalhori, A.B. Junior, Effects of the bleaching procedures on enamel micro-hardness: Plasma Arc and diode laser comparison, Laser therapy 24 (3) (2015) 173–177.
[17] A. Gutiérrez-Corrales, Y. Rizcala-Orlando, P. Montero-Miralles, G. Volland, J.L. Gutiérrez-Pérez, D. Torres-Lagares, M.A. Serrera-Figallo, Comparison of diode laser–Oral tissue interaction to different wavelengths. In vitro study of porcine periodontal pockets and oral mucosa, Medicina Oral, Patología Oral y Cirugía Bucal. 25 (March (2)) (2020) e224.
[18] M.A. Al-Maliky, M. Frentzen, J. Meister, Artificial Caries Resistance in Enamel after Topical Fluoride Treatment and 445 nm Laser Irradiation, BioMed research international 2019 (2019).
[19] I. Katalinić, A. Budimir, Z. Bošnjak, S. Jakovljević, I. Anić, The photo-activated and photo-thermal effect of the 445/970 nm diode laser on the mixed biofilm inside root canals of human teeth in vitro: A pilot study, Photodiagnosis and photodynamic therapy 26 (June) (2019) 277–283.
[20] T. Drost, S. Reimann, M. Frentzen, J. Meister, Effectiveness of photopolymerization in composite resins using a novel 445-nm diode laser in comparison to LED and halogen bulb technology, Lasers in medical science 34 (June (4)) (2019) 729–736.
[21] H.W. Choung, S.H. Lee, A.R. Ham, N.R. Lee, B. Kim, K.M. Pang, J.W. Jahng, J.H. Lee, Effectiveness of Low-Level Laser Therapy with a 915 Nm Wavelength Diode Laser on the Healing of Intraoral Mucosal Wound: An Animal Study and a Double-Blind Randomized Clinical Trial, Medicina 55 (August (8)) (2019) 405.
[22] G. Mergoni, P. Vescovi, S. Belletti, J. Uggeri, S. Nammour, R. Gatti, Effects of 915 nm laser irradiation on human osteoblasts: a preliminary in vitro study, Lasers in medical science 33 (August (6)) (2018) 1189–1195.
[23] B.H. Kivanç, H.D. Arisu, Öİ Ulusoy, B.C. Sağlam, G. Görgül, Effect of light-activated bleaching on pulp chamber temperature rise: An in vitro study, Australian Endodontic Journal 38 (August (2)) (2012) 76–79.
[24] R.J. De Moor, J. Verheyen, P. Verheyen, A. Diachuk, M.A. Meire, P.J. De Coster, M. De Bruyne, F. Keulemans, Laser teeth bleaching: evaluation of eventual side effects on enamel and the pulp and the efficiency in vitro and in vivo, The Scientific World Journal. 2015 (March) (2015).
[25] M.A. Al-Maliky, M. Frentzen, J. Meister, Artificial Caries Resistance in Enamel after Topical Fluoride Treatment and 445 nm Laser Irradiation, BioMed research international 2019 (2019).
[26] P. Beard, Biomedical photoacoustic imaging, Interface focus 1 (August (4)) (2011) 602–631.
[27] A. Braun, M. Kettner, M. Berthold, J.S. Wenzler, P.G. Heymann, R. Frankenberger, Efficiency of soft tissue incision with a novel 445-nm semiconductor laser, Lasers in medical science 33 (January (1)) (2018) 27–33.
[28] M.T. de Magalhaes, R.T. Basting, E.R. de Almeida, J.E. Pelino, Diode laser effect on enamel micro-hardness after dental bleaching associated with Fluoride, Photomedicine and laser surgery 27 (6) (2009) 937–941.
[29] M. Sulieman, J.S. Rees, M. Addy, Surface and pulp chamber temperature rises during tooth bleaching using a diode laser: a study in vitro, British dental journal 200 (June (11)) (2006) 631–634.
[30] P.A. Oskoee, E.J. Navimipour, S.S. Oskoee, N. Moosavi, Effect of 10% sodium ascorbate on bleached bovine enamel surface morphology and microhardness, The open dentistry journal 4 (2010) 207.
[31] D. Dionysopoulos, D. Strakas, E. Koliniotou-Koumpia, The influence of a novel in-office tooth whitening procedure using an Er,Cr:YSGG laser on enamel surface morphology, Lasers in surgery and medicine. 47 (6) (2015) 503–511.
[32] Z.B. Kutuk, E. Ergin, F.Y. Cakir, S. Gurgan, Effects of in-office bleaching agent combined with different desensitizing agents on enamel, Journal of Applied Oral Science. 27 (2019).
[33] O. Araujo Fde, L.N. Baratieri, E. Araujo, In situ study of in-office bleaching procedures using light sources on human enamel micro-hardness, Operative dentistry 35 (2) (2010) 139–146.
[34] H. Moosavi, F. Darvishzadeh, The influence of post bleaching treatments in stain absorption and microhardness, The open dentistry journal 10 (2016) 69.
[35] S. Alshammery, Evaluation of Light Activation on In-office Dental Bleaching: A Systematic Review, The journal of contemporary dental practice 20 (November (11)) (2019) 1355.
[36] G.E. Romanos, Clinical applications of the Nd: YAG laser in oral soft tissue surgery and periodontology, Journal of clinical laser medicine & surgery 12 (April (2)) (1994) 103–108.
[37] G. Romanos, G.H. Nentwig, Diode laser (980 nm) in oral and maxillofacial surgical procedures: clinical observations based on clinical applications, Journal of clinical laser medicine & surgery 17 (October (5)) (1999) 193–197.
[38] C. Zhang, X. Wang, J. Kinoshita, B. Zhao, T. Toko, Y. Kimura, et al., Effects of KTP laser irradiation, diode laser, and LED on tooth bleaching: a comparative study, Photomedicine and laser surgery. 25 (2) (2007) 91–95.
[39] M. Marcondes, M.P. Paranhos, A.M. Spohr, E.G. Mota, I.N. da Silva, A.A. Souto, et al., The influence of the Nd:YAG laser bleaching on physical and mechanical properties of the dental enamel. Journal of biomedical materials research Part B, Applied biomaterials. 90 (1) (2009) 388–395.
[40] R.F. Mondelli, T.R. Gabriel, F.A. Rizzante, A.C. Magalhães, J.F. Bombonatti, S.K. Ishikiriama, Do different bleaching protocols affect the enamel microhardness? European Journal of Dentistry. 9 (January (01)) (2015) 025–030.
[41] M. Ghanbarzadeh, F. Ahrari, M. Akbari, H. Hamzei, Microhardness of demineralized enamel following home bleaching and laser-assisted in office bleaching, Journal of clinical and experimental dentistry 7 (July (3)) (2015) e405.
[42] N.U. Wetter, M.C. Barroso, J.E. Pelino, Dental bleaching efficacy with diode laser and LED irradiation: an in vitro study, Lasers in Surgery and Medicine 35 (October (4)) (2004) 254–258.
[43] H.W. Choung, S.H. Lee, A.R. Ham, N.R. Lee, B. Kim, K.M. Pang, J.W. Jahng, J.H. Lee, Effectiveness of Low-Level Laser Therapy with a 915 Nm Wavelength Diode Laser on the Healing of Intraoral Mucosal Wound: An Animal Study and a Double-Blind Randomized Clinical Trial, Medicina 55 (August (8)) (2019) 405.
[44] G. Mergoni, P. Vescovi, S. Belletti, J. Uggeri, S. Nammour, R. Gatti, Effects of 915 nm laser irradiation on human osteoblasts: a preliminary in vitro study, Lasers in medical science 33 (August (6)) (2018) 1189–1195.