Abstract: The bleaching efficacy of common bleaching agents and deionized water treated with non-thermal atmospheric pressure plasma in the pulp chamber for nonvital tooth bleaching was evaluated. A total of 120 extracted human maxillary first incisors were stained using human blood. Teeth were randomly divided into eight groups (n = 15). In the first four groups, teeth were bleached using 35% hydrogen peroxide gel, 37% carbamide peroxide gel, 2:1 (w/v) sodium perborate paste, and deionized water for 30 min. In the remaining groups, bleaching agents were treated with non-thermal atmospheric plasma for 5 min inside the pulp chamber. Overall color changes (ΔE) were determined using Commission Internationale de L’Eclairage Lab Colour System. The plasma-assisted tooth bleaching has not increased tooth temperature beyond 37°C. Bleaching efficacies of bleaching agents were significantly improved when treated with non-thermal atmospheric plasma compared to their application (P < 0.05). A remarkable bleaching effect was obtained when bleaching agents were substituted with water and when treated with non-thermal atmospheric plasma. Non-thermal atmospheric plasma treatment could be a novel tool for activation of bleaching agents in the pulp chamber for nonvital tooth bleaching procedure. Moreover, water could be used as a novel bleaching agent when treated with the non-thermal atmospheric plasma to eliminate possible risks which might arise from peroxide-containing agents.

Keywords: bleaching agent; blood-stained human teeth; non-thermal atmospheric pressure plasma; nonvital tooth bleaching.

Introduction

Tooth bleaching is a common aesthetic procedure in dentistry (1). Tooth discoloration is classified as intrinsic and extrinsic depending on the accumulation of chromogens either on the tooth surface or within the bulk volume of the tooth (2). Hemorrhage due to trauma, tetracycline use, infection, pulp necrosis, medications, filling materials, and restorations in the root canal are the main causes of intrinsic discoloration (3,4). Nonvital bleaching is an established clinical procedure for the elimination of intrinsic discoloration (5). Hydrogen peroxide (HP), carbamide peroxide (CP), and sodium perborate (SP) are the most common bleaching agents used for nonvital tooth bleaching (6,7). CP and SP act as a hydrogen peroxide reservoir and release hydrogen peroxide when dissociate (8). Even though the exact mechanism of tooth bleaching is not fully understood,
one possible mechanism is the oxidation and dissolution of long-chained chromogen molecules into smaller and brighter molecules (9,10). Reactive oxygen species (ROS), in particular hydroxyl radical (·OH), released from bleaching agents, causes cleavage of double bonds in chromogens via oxidation (11,12). Light and heat application enhances tooth bleaching by accelerating the dissociation of hydrogen peroxide (13). Nevertheless, light- and/or heat-activated bleaching methods might cause an increase in tooth temperature. Consequently, the tooth temperature might exceed safe limits, which was reported as 42°C for irreversible pulpal damage and 47°C for bone necrosis (14,15). Moreover, use of hydrogen peroxide for nonvital bleaching carries potential risks such as cervical root resorption, crown fracture and worsens mechanical properties on enamel due to reduced microhardness (16). Risks originating from hydrogen peroxide could also be attributed to CP and SP as well, since they show bleaching activity through release of hydrogen peroxide from their structure (11,17-19). Thus, an effective and safe method to activate bleaching agents and a non-toxic, novel bleaching agent are needed for a safer nonvital bleaching procedure.

Plasma is the fourth state of matter and is defined as ionized gas. It is a complex mixture of free electrons, electrically excited particles, free radicals, reactive oxygen, and reactive nitrogen species (RNS), which make plasma a highly reactive medium (20). Depending on the thermal equilibrium of free electrons and ions, plasmas are classified as thermal (or hot) and non-thermal (or cold) plasmas. Non-thermal plasmas (NTP) could be applied to biological tissues for various purposes such as disinfection, coagulation, and wound healing, since it could be generated at room temperature (21). Various dental applications of non-thermal atmospheric plasmas including tooth bleaching have been reported by several groups (22-24).

In this study, a dielectric barrier discharge (DBD) air plasma has been utilized to enhance bleaching activity of common bleaching agents and to activate deionized water (DIW) for nonvital bleaching purpose as opposed to previous studies which have utilized plasma jets with a gas flow (23-25).

The aim of this study was to analyze bleaching efficacy of the most common bleaching agents when activated with direct, non-thermal atmospheric DBD air plasma treatment. Moreover, it was hypothesized that NTP treatment enhances the bleaching efficacy of common bleaching agents and thus could accelerate the entire bleaching process.

Furthermore, NTP treatment leads to the activation of various liquids including DIW via formation and diffusion of ROS, RNS and free radicals formed during plasma treatment (26). Therefore, the authors also hypothesized that NTP treatment causes activation of DIW inside the pulp chamber to induce nonvital tooth bleaching.

Materials and Methods

Plasma Source
Non-thermal atmospheric DBD air plasma was used for nonvital tooth bleaching experiments as shown in Fig. 1A and 1B. A custom-made DBD electrode was connected to a microsecond pulsed alternating current power supply (Advanced Plasma Solutions, Malvern, PA, USA) that was operated at 31 kV peak to peak voltage and 1.5 kHz frequency with 6 W power output. The DBD electrode was fabricated by covering the surface of a cylindrical copper rod with 1 mm-thick glass slide. A high-voltage cable was soldered to copper, and exposed surfaces of copper were insulated using polyethylene housing. The plasma discharge was generated by maintaining 2 mm of the discharge gap between the surface of the DBD electrode and the bleaching agent inside the pulp chamber.

Sample Preparation
The study protocol was approved by the İzmir Katip Çelebi University Non-Interventional Clinical Studies Institutional Review Board (#15, Feb 15, 2015). Human maxillary central incisors were collected in İzmir Katip Çelebi University, Faculty of Dentistry, Department of Oral and Maxillofacial Surgery. Teeth were examined under stereomicroscope (Carl Zeiss Jena GmbH, Jena, Germany) with 5× magnification. Any teeth with cracks, deformations, and/or caries were excluded and replaced with new ones. Teeth were disinfected in 10% formalin solution for 48 h. Crowns were polished using a polishing brush to remove surface staining. Endodontic access cavities were prepared using a diamond fissure and round burs under water cooling. Root canals were enlarged with a reciprocating endodontic micromotor (Reciproc, VDW, Munich, Germany), and filled with single cone gutta-percha using an epoxy resin-based root canal sealer (Meta Biomed, Cheongju, Republic of Korea). Excess gutta-percha in the canal orifice was removed using a heated plugger. Then, the access cavities were filled with a temporary filling material (Meta Biomed, Cheongju, Republic of Korea), and teeth were kept on humid sponges in an incubator at 37°C for 7 days.

Tooth Staining
Samples were stained using expired blood. Each sample was transferred into individual microcentrifuge tubes...
containing 4 mL of blood. Samples were centrifuged at 3,400 revolutions per minute (rpm) for 20 min. Approximately 1.5 mL of plasma was removed, and samples were centrifuged for another 20 min. Centrifugation was performed twice a day for 14 days for each sample. Extracoronal staining was removed using polishing brushes in all experimental groups. Teeth with vita color of C3 or darker were included in the study.

Optimization of Plasma Treatment Time
A series of preliminary plasma bleaching experiments were carried out to determine the optimum plasma treatment time. Approximately 50 µL of 35% HP were placed in pulp chambers, and teeth were treated for 1, 3, 5, 7, and 10 min by maintaining 2 mm of the discharge gap between the surface of the DBD electrode and HP in the pulp chamber (Fig. 1A, n = 5). After completion of plasma treatment, bleaching agents were removed, teeth were soaked in artificial saliva and color measurements, and color change (ΔE) was plotted versus treatment time.

Tooth Color Measurement and Analysis of Bleaching Efficacy
Tooth color was measured using a dental spectrophotometer on a gray background (Spectro Shade Micro, Verona, Italy). Color measurements were repeated three times for each sample and average L∗, a∗ and b∗ values, which represents lightness, redness-greenness, and yellowness-blueness respectively, were recorded. Color measurements were performed before staining of samples (L0∗, a0∗, b0∗ values were recorded), after staining samples (L1∗, a1∗, b1∗ values were recorded), after bleaching experiments (L2∗, a2∗, b2∗ values were recorded), and 2 weeks after bleaching experiments (L3∗, a3∗, b3∗ values were recorded). Differences (Δ) in L∗, a∗ and b∗ values were determined. Overall color change (ΔE) was calculated using the following equation:

\[ \Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \]

ΔE1 value represents the efficacy of the staining procedure and was determined by calculating L1∗−L0∗, a1∗−a0∗ and b1∗−b0∗. ΔE2 value represents the efficacy of the bleaching procedure and was determined by calculating L2∗−L1∗, a2∗−a1∗ and b2∗−b1∗. ΔE3 value represents the color relapse in consequence of rehydration of samples in artificial saliva for 2 weeks and was determined by calculating L3∗−L2∗, a3∗−a2∗, and b3∗−b2∗.

Bleaching Experiments
Samples were randomly distributed to eight groups to have 15 teeth in each group. Experimental groups were determined as HP, CP, SP, and DIW (as control group) only, HP+NTP, CP+NTP, SP+NTP, and DIW+NTP. In bleaching experiments without NTP treatment, approximately 50 µL of 35% HP gel (Ultradent, South Jordan, UT, USA), 50 µL of 37% CP gel (FGM, Joinville, Brazil), and 2:1 (w/v) SP paste (Sigma-Aldrich, St. Louis MO, USA), which was prepared by mixing SP and DIW by 2:1 (w/v), were separately placed into pulp chambers of teeth and held for 30 min. After 30 min of bleaching period, bleaching agents were removed, pulp chambers were washed with 1 mL of DIW to completely remove remnants of bleaching agents, and samples were soaked in artificial saliva solution for 5 min. Color measurements were then performed using a dental spectrophotometer on a gray background three times for each sample. In bleaching experiments in which bleaching agents and DIW were treated with NTP, similarly 50 µL of 35% HP gel, 50 µL of 37% CP gel, 2:1 (w/v) SP paste, and 50 µL of DIW were separately placed in pulp chambers, and teeth were treated with
non-thermal atmospheric DBD air plasma for 5 min by maintaining 2 mm of the discharge cap between the surface of the DBD electrode and the bleaching agent in the pulp chamber (Fig. 1A and 1B). After completion of plasma treatment bleaching agents were removed, pulp chambers were washed with 1 mL of DIW to completely remove remnants of bleaching agents, teeth soaked in artificial saliva, and color measurements were performed as described. Following completion of each bleaching procedure and color measurement, samples were soaked in 10% of sodium ascorbate solution to remove oxidation products and kept in artificial saliva solution at 37°C for 2 weeks. After 2 weeks, color measurements were performed to determine the stability of the bleaching procedure.

**Measurement of Tooth Temperature**

Temperature of teeth was measured from crown surfaces before and immediately after completion of plasma treatment using a calibrated infrared thermometer (Mesitaş, İstanbul, Turkey). Temperature measurements were performed three times before and after plasma treatment for each sample, and average temperature values were calculated.

**Statistical Analysis**

Statistical analyses were performed using SPSS 20.0 (SPSS Inc., Chicago, IL, USA). The normality of data distribution was tested using Shapiro-Wilk test. Color change measurements and temperature measurements were determined as parametric. Color changes were analyzed by one-way analysis of variance and a post hoc Bonferroni or Dunnett’s C test (when the homogeneity of variance was <0.05). Temperature changes were analyzed by Student’s t-test. A value of $P < 0.05$ represents statistical significance.

**Results**

**Optimization of Plasma Treatment Time**

As depicted in Fig. 2, the bleaching efficacy of the 35% HP gel when treated with NTP increased with increasing plasma treatment time until 5 min of plasma treatment. $\Delta E$ values were determined as 2.87, 6.78, and 12.56 for 1, 3, and 5 min of plasma treatment, respectively. Further plasma treatment durations did not improve the bleaching efficacy, and $\Delta E$ values reached a plateau with 13.08 and 13.38 for 7 and 10 min of the plasma treatment respectively. Therefore, plasma treatment time was determined as 5 min for further nonvital bleaching experiments.

**Bleaching Efficacy**

The staining procedure of the teeth caused a uniform color change in all groups with a mean $\Delta E_1$ value of 16.07 (data not shown). There was no statistically significant difference in $\Delta E_1$ values among groups.

Utilization of NTP treatment with bleaching agents has statistically significantly improved the efficacies of bleaching agents compared to their application ($P < 0.05$; Fig 3A). NTP treatment increased the bleaching efficacies of HP, CP, and SP by 4.72, 9.58, and 11.52 folds, respectively, compared to their use per se. Plasma treatment of DIW in the pulp chamber also led to a strong bleaching efficacy that was comparable to those obtained when common bleaching agents were treated with NTP ($P < 0.05$). The $\Delta E_2$ values for DIW+NTP and DIW alone groups were measured as 13.19 and 0.46, respectively. Moreover, as shown in Figure 3B-E, improved bleaching efficacies of bleaching agents and DIW upon treatment with plasma could be evidently observed. The bleaching efficacies of common bleaching agents when treated with NTP did not represent any statistically significant difference ($P > 0.05$). When common bleaching agents were used, HP has shown a statistically significantly higher bleaching efficacy compared to SP and CP ($P < 0.05$).

**Stability of Bleaching Efficacy**

The color relapse due to rehydration was measured 2 weeks after the completion of bleaching procedures and recorded as $\Delta E_3$. As demonstrated in Table 1, $\Delta E_3$ values were determined as 1.94, 1.61, 1.63, and 1.79 for HP+NTP, CP+NTP, SP+NTP, and DIW+NTP groups, respectively, and were significantly higher than those of HP, CP, SP alone, and DIW groups which were determined as 0.51, 0.49, 0.50, and 0.26, respectively ($P < 0.05$).
Tooth Temperature Change

Prior to plasma treatment, the mean teeth temperatures were measured about 22°C in all experimental groups. In all NTP groups, temperature of samples was below the normal body temperature of 37°C after completion of NTP treatment. After the bleaching procedure with non-thermal atmospheric plasma, the temperature of samples increased to 30.79°C, 25.28°C, 27.86°C, and 28.02°C in HP+NTP, CP+NTP, SP+NTP, and DIW+NTP groups, respectively, as shown in Fig. 4.

Discussion

This study was carried out not only to evaluate the enhancement of nonvital tooth bleaching efficacies of common bleaching agents when activated with NTP, but also to investigate bleaching efficacy of a safer agent—DIW—when activated with NTP to substitute it with common bleaching agents.

Hydrogen peroxide and peroxide releasing agents such as CP and SP are employed for tooth bleaching purposes in routine clinical application (1,8). However, these agents might present several risks to the tooth and might remain ineffective to achieve the desired bleaching effect (11,27). Therefore, various light and heat sources were employed to activate bleaching agents by promoting the dissociation of hydrogen peroxide to •OH radical (28). Nevertheless, the use of heat and/or light sources might increase the temperature in the pulp chamber above the safe limits (29). Therefore, faster and safer bleaching procedure is needed.

In this study, non-thermal atmospheric plasma treatment of common bleaching agents and DIW was limited to 5 min based on the plasma treatment time optimiza-

Table 1 Color change (ΔE₃) after rehydration of teeth in artificial saliva for 2 weeks

| Bleaching agent          | mean ΔE₃ ± SD | P value |
|--------------------------|--------------|---------|
| deionized water          | 0.2 ± 0.09   | 1.8 ± 0.40 | 0.000* |
| 35% hydrogen peroxide    | 0.5 ± 0.21   | 1.9 ± 0.63 | 0.000* |
| 37% carbamide peroxide   | 0.5 ± 0.26   | 1.6 ± 0.73 | 0.000* |
| 2:1 (w/v) sodium perborate | 0.5 ± 0.14   | 1.6 ± 0.45 | 0.000* |

Fig. 4 Tooth temperature measurements before and after non-thermal plasma treatment. Plasma-assisted tooth bleaching procedure did not cause an increase in tooth temperature beyond normal body temperature.
tion experiments. As demonstrated in Fig. 2, ΔE value reached the plateau. These results could be due to the consumption of hydrogen peroxide in 35% HP gel or limited diffusion of plasma-generated species due to loss of water from the gel after 5 min of NTP treatment.

As demonstrated in Figure 3A, NTP treatment has improved the bleaching efficacy of common bleaching agents compared to their applications. It is believed that ‘OH radical is the key radical species for tooth bleaching due to the presence of an unpaired electron, which makes it an unstable and highly reactive substance (10,30). As a result of its reactivity, ‘OH radical breaks chromophores on the tooth to smaller molecules by capturing electrons which then causes bleaching (31-33). Lee et al. has shown the release of ‘OH radical from H2O2 when treated with NTP using electron spin resonance technique (31). In the present study, it could be postulated that common bleaching agents were activated via plasma treatment which increases dissociation of hydrogen peroxide to ‘OH radical.

Utilization of DBD plasma electrode yielded higher ΔE values in shorter plasma treatment durations compared to previously published studies which have employed plasma jet with gas flow. The flow of the gas for generation of plasma jet removes the bleeding agent from the tooth and requires renewal of bleeding agent (22). However, the renewal of a bleeding agent is not because there was no gas flow in DBD treatment. Therefore, bleeding agents could stay in the pulp chamber during the treatment period. Thus, continuous formation and contact of chemical species responsible for bleeding with tooth could be obtained and higher bleaching efficacy could be achieved.

Despite the lack of peroxide reservoir in DIW unlike common bleeding agents, the plasma treatment of DIW in the pulp chamber also resulted in remarkable bleeding effect comparable to those achieved with plasma-activated common bleeding agents. This effect could be attributed to the formation of various ROS and RNS in plasma-treated water in the pulp chamber which makes it a reservoir of the ROS and RNS that might play roles on tooth bleaching as reported previously in several studies (22,26,34,35). Furthermore, lower consistency of water compared to common bleeding agents used in the present study, which were in the form of gel or paste, allows more efficient diffusion of plasma-generated ROS and RNS into water.

During formation of plasma discharge, various ROS and RNS are generated, and these species have been detected in several plasma-treated liquids (26,36,37). Diffusion of ROS and RNS that are generated during plasma formation in the gas phase and reaction of these ROS and RNS with liquid causes ROS and RNS in plasma-treated liquids (38). Thus, plasma-treated liquids are considered complex mixtures of ROS and RNS, including, hydrogen peroxide (H2O2), hydroxyl radical (‘OH), ozone (O3), atomic oxygen (O), superoxide (O2–), singlet oxygen (‘O2), hydroperoxyl (HO2), nitric oxide (NO), nitrate (NO3–), and nitrite (NO2–). Moreover, plasma treatment generates ultraviolet (UV) light (39,40). In this way, NTP treatment serves as source of various ROS and RNS that might play roles in tooth bleaching in addition to promoting dissociation of hydrogen peroxide for generation of ‘OH radical. ‘OH generation upon treatment of common bleaching agents and DIW with NTP in the pulp chamber is a result of reaction of H2O2 with plasma-generated species including atomic oxygen, ozone, and superoxide (41). In addition, UV light formed during plasma treatment leads to dissociation of hydrogen peroxide to form ‘OH radical (22). As previously reported by various groups, NO3– and NO2– are also generated in plasma-treated liquids, and these nitrogen species are also being thought to contribute to tooth bleaching by inducing acid pickling on tooth (22,42).

Moreover, in this study, tooth discoloration could be considered a factor for improved bleaching effect when common bleeding agents and DIW were treated with NTP. Pulpal hemorrhage is one of the main causes of internal discoloration of teeth. When blood vessels are ruptured due to trauma, blood is accumulated in the pulp chamber which leads erythrocytes to enter dentin tubules. Erythrocytes might then undergo hemolysis and hemoglobin might be liberated. Subsequently, the decomposition of hemoglobin releases iron, which then reacts with hydrogen sulfide to generate iron sulfide (FeS2), the main cause for internal tooth discoloration. In this study, teeth were stained using blood to mimic internal discoloration mechanism (23,43). Plasma-generated superoxide (O2–) causes release of ferrous ions (Fe2+) via dissociation of iron-sulfur clusters. Liberated ferrous (Fe2+) ions act as catalyst in Fenton reaction for formation of ‘OH from hydrogen peroxide via following reactions (44,45):

\[
\text{Fe}^{2+} + \text{H}_2\text{O}_2 \rightarrow \text{Fe}^{3+} + \cdot\text{OH} + \text{OH}^- \quad (1)
\]

\[
\text{Fe}^{3+} + \text{H}_2\text{O}_2 \rightarrow \text{Fe}^{2+} + \cdot\text{OOH} + \text{H}^+ \quad (2)
\]

Color relapse due to rehydration was significantly higher in the NTP groups compared to groups in which bleaching agents were used by themselves. However, there were no statistically significant differences in the color relapse among the only bleeding agent groups or among the NTP treatment groups. The higher color relapse in the NTP-treated groups might originate from
their higher ∆E₂ values, possibly showing that the more the whitening, the more color relapse.

In this study, tooth temperature was measured before and immediately after completion of the bleaching procedure, as opposed to continuous temperature measurements in previous plasma-assisted tooth bleaching studies. As demonstrated in previous studies the tooth temperature during plasma treatment increases immediately after initiation of plasma treatment and then temperature change is equilibrated (23,31,46). Therefore, it could be postulated that by the end of the plasma treatment, teeth reached the maximum possible temperature that is induced by bleaching which was below 37°C of the body temperature. Tooth temperature exceeding 42°C leads to irreversible pulpitis and induces pulpal tissue degradation and 47°C might cause bone necrosis (14,15). The temperature increase in teeth in this study was below the normal body temperature. Therefore, activation of common bleaching agents and DIW in the pulp chamber could be considered thermally safe.

NTP treatments have been reported as non-toxic methods in various applications (47-49). However, further studies are needed to validate that plasma-generated ROS, RNS, and free radicals, which are crucial for bleaching efficacy, do not induce any toxicity in the tooth.

In conclusion, fast and effective bleaching of nonvital discolored tooth could be achieved without any thermal damage when DIW is treated with non-thermal DBD plasma in the pulp chamber. Therefore, the disadvantages of common bleaching agents could be eliminated when DIW is replaced with common bleaching agents and treated with NTP. Moreover, combination of common bleaching agents with NTP treatment in the pulp chamber leads to increased bleaching effect on nonvital tooth compared to use of common bleaching agents.

Conflict of interest
The authors have no conflict of interest to declare.

References
1. Carey CM (2014) Tooth whitening: what we now know. J Evid Based Dent Pract 14, 70-76.
2. Watts A, Addy M (2001) Tooth discoloration and staining: a review of the literature. Br Dent J 190, 309-316.
3. Mortazavi H, Baharvand M, Khodadoustan A (2014) Colors in tooth discoloration: a new classification and literature review. Int J Clin Dent 7, 17-27.
4. Abdelkader NN (2015) Modified technique for nonvital tooth bleaching: a case report. Electron Physician 7, 1423-1426.
5. Plotino G, Buono L, Grande NM, Pameijer CH, Somma F (2008) Nonvital tooth bleaching: a review of the literature and clinical procedures. J Endod 34, 394-407.
6. Lim MY, Lum SO, Poh RS, Lee GP, Lim KC (2004) An in vitro comparison of the bleaching efficacy of 35% carbamide peroxide with established intracoronal bleaching agents. Int Endod J 37, 483-488.
7. Demarco FF, Conde MC, Ely C, Torre EN, Costa JR, Fernández MR et al. (2013) Preferences on vital and nonvital tooth bleaching: a survey among dentists from a city of southern Brazil. Braz Dent J 24, 527-531.
8. Valera MC, Camargo CH, Carvalho CAT, de Oliveira LD, Camargo SE, Rodrigues CM (2009) Effectiveness of carbamide peroxide and sodium perborate in non-vital discolored teeth. J Appl Oral Sci 17, 254-261.
9. Oltu Ü, Gürsan S (2000) Effects of three concentrations of carbamide peroxide on the structure of enamel. J Oral Rehabil 27, 332-340.
10. Joiner A (2006) The bleaching of teeth: a review of the literature. J Dent 34, 412-419.
11. Li Y, Greenwall L (2013) Safety issues of tooth whitening using peroxide-based materials. Br Dent J 215, 29-34.
12. Nam SH, Lee HW, Hong JW, Lee HJ, Kim GC (2014) Enhanced long-term color stability of teeth treated with hydrogen peroxide and non-thermal atmospheric pressure plasma jets. Plasma Process Polym 11, 1010-1017.
13. Bhutani N, Venigalla BS, Patil JP, Singh TV, Jyotsna SV, Jain A (2016) Evaluation of bleaching efficacy of 37.5% hydrogen peroxide on human teeth using different modes of activations: an in vitro study. J Conserv Dent 19, 259-263.
14. Eriksson A, Albrektsson T, Grane BM, McQueen D (1982) Thermal injury to bone: a vital-microscopic description of heat effects. Int J Oral Surg 11, 115-121.
15. Augustin G, Davila S, Mihoci K, Udljak T, Vedrina DS, Antabak A (2008) Thermal osteonecrosis and bone drilling parameters revisited. Arch Orthop Trauma Surg 128, 71-77.
16. Tredwin CJ, Naik S, Lewis NJ, Scully C (2006) Hydrogen peroxide tooth-whitening (bleaching) products: review of adverse effects and safety issues. Br Dent J 200, 371-376.
17. Weiger R, Kuhn A, Löst C (1994) Radicular penetration of hydrogen peroxide during intra-coronal bleaching with various forms of sodium perborate. Int Endod J 27, 313-317.
18. McCracken MS, Haywood VB (1996) Demineralization effects of 10 percent carbamide peroxide. J Dent 24, 395-398.
19. Meireles SS, Heckmann SS, Leida FL, dos Santos IS, Della Bona Â, Demarco FF (2008) Efficacy and safety of 10% and 16% carbamide peroxide tooth-whitening gels: a randomized clinical trial. Oper Dent 33, 606-612.
20. Weltmann KD, von Woedtke T (2016) Plasma medicine—current state of research and medical application. Plasma Phys Controlled Fusion 59, 014031.
21. Fridman G, Friedman G, Gutsol A, Shekhhter AB, Vasilets VN, Fridman A (2008) Applied plasma medicine. Plasma Process Polym 5, 503-533.
22. Sun P, Pan J, Tian Y, Bai N, Wu H, Wang L et al. (2010) Tooth whitening with hydrogen peroxide assisted by a direct-
current cold atmospheric-pressure air plasma microjet. IEEE Trans Plasma Sci 38, 1892-1896.

23. Park J, Nam SH, Kwon HC, Mohamed AA, Lee JK, Kim GC (2011) Feasibility of nonthermal atmospheric pressure plasma for intracoronal bleaching. Int Endod J 44, 170-175.

24. Claiborne D, McCombs G, Lemaster M, Akman M, Laroussi M (2014) Low-temperature atmospheric pressure plasma enhanced tooth whitening: the next-generation technology. Int J Dent Hyg 12, 108-114.

25. Han GJ, Kim JH, Chung SN, Chun BH, Kim CK, Seo DG et al. (2011) Feasibility of nonthermal atmospheric pressure plasma for intracoronal bleaching. Int Endod J 44, 170-175.

26. Claiborne D, McCombs G, Lemaster M, Akman M, Laroussi M (2014) Low-temperature atmospheric pressure plasma enhanced tooth whitening: the next-generation technology. Int J Dent Hyg 12, 108-114.

27. Han GJ, Kim JH, Chung SN, Chun BH, Kim CK, Seo DG et al. (2011) Feasibility of nonthermal atmospheric pressure plasma for intracoronal bleaching. Int Endod J 44, 170-175.

28. Park J, Nam SH, Kwon HC, Mohamed AA, Lee JK, Kim GC (2011) Feasibility of nonthermal atmospheric pressure plasma for intracoronal bleaching. Int Endod J 44, 170-175.

29. Claiborne D, McCombs G, Lemaster M, Akman M, Laroussi M (2014) Low-temperature atmospheric pressure plasma enhanced tooth whitening: the next-generation technology. Int J Dent Hyg 12, 108-114.

30. Han GJ, Kim JH, Chung SN, Chun BH, Kim CK, Seo DG et al. (2011) Feasibility of nonthermal atmospheric pressure plasma for intracoronal bleaching. Int Endod J 44, 170-175.

31. Han GJ, Kim JH, Chung SN, Chun BH, Kim CK, Seo DG et al. (2011) Feasibility of nonthermal atmospheric pressure plasma for intracoronal bleaching. Int Endod J 44, 170-175.