The Use of the KTP Laser, an Added Value for Tooth Bleaching

Roeland J. G. De Moor[a], Katrien Vanderstricht[b]

[a] *Professor, Department of Operative Dentistry and Endodontology, Ghent University, Ghent University Dental School, Gent, Belgium.*
[b] *Clinical Resident, Department of Operative Dentistry and Endodontology, Ghent University, Ghent University Dental School, Gent, Belgium.*

Abstract: Different external bleaching procedures utilizing highly concentrated hydrogen peroxide formulations can be used for tooth bleaching and tooth whitening. Whitening is the removal of superficial discoloration of the teeth, whereas bleaching constitutes the removal of stains on and in tooth substance by means of oxygen radicals. Light can be used to enhance or accelerate the bleaching process. In most cases, the effect of light is limited to heating of the bleaching formulation and this process differs from “true photobleaching”. Photobleaching or photodynamic bleaching is a process where light from a laser or non-coherent light source is used to drive molecular changes in light-sensitive compounds, and where the discoloration or bleaching of the teeth is caused as a result of the generation of reactive oxygen species. Secondly, it is also possible to photobleach colored organic compounds and especially those that are inherently resistant to the action of the oxygen free radicals. At present, true photobleaching can only be performed with the KTP laser (532 nm) in conjunction with a red colored highly concentrated hydrogen peroxide gel. Furthermore, it has also been demonstrated that the use of the KTP laser with the Smart Bleach system is safe: no intrapulpal temperature elevations beyond 5.5°C have been registered, and there is no risk of enamel microhardness decrease. KTP laser bleaching can be considered a noninvasive esthetic procedure, and hence is the least invasive procedure of what is called today minimally invasive dentistry.

Keywords: laser bleaching, laser tooth whitening, KTP laser, photobleaching, power bleaching, tetracyclines.

J Oral Laser Applications 2009; 9: 219-226.

The concept of high concentration hydrogen peroxide used in-office to produce an almost immediate bleaching result dates back to the early 1900s.[1] To accelerate the bleaching process, the bleaching agent can be additionally heat activated. This idea of power bleaching dates back to 1918, when Abbot reported the use of high-intensity light to increase the temperature of hydrogen peroxide.[2] The use of direct heating has gradually decreased in recent years. It has been replaced by other energy sources, such as plasma-arc devices, halogen lamps, light emitting diodes, and other light sources.

Lamps emitting long wavelengths, ie, visual spectrum or the larger invisible infrared (IR) spectrum, have lower-energy photons with a high thermal character, and these may induce unfavorable thermal effects. Shorter wavelengths, such as the argon laser (λ = 488 nm) or KTP laser (λ = 532 nm; Kalium-Titanyl-Phosphat [German], or Potassium-Titanyl-Phosphate [English]) have higher energy photons with less direct thermal characteristics.[3]

Data on mechanisms of action and efficacy of laser, and light- and heat-activated dental bleaching are still limited.[4] However, it is common to all described light-activated bleaching procedures that light is used in addition to the application of a bleaching agent (such as a bleaching gel) rather than on its own. It is the effect the light or heat has on the chemical bleaching product (gel) rather than on the tooth substance itself and the chromophores it contains that may lead to an increased bleaching effect.

As mechanisms of action, thermocatalysis (acceleration of the release of hydroxyl radicals from peroxide by a temperature rise) and photolysis (release of hydroxyl radicals from hydrogen peroxide through direct excitation by light) are described. In order to increase light absorption, some bleaching products are mixed with specific colorants, eg, an orange-red color increases the absorption of blue light. The addition of small silica particles in the nanometer or lower micrometer scale gives these products a bluish appearance and increases the absorption of red and infrared light. The energy required for photolysis can only be provided by high frequency light (λ = 248 nm or lower UV C). which makes its use in the mouth impossible. Hence, the light source becomes an important factor for not only the safety of light-activated bleaching procedures but also for its efficacy.

LIGHT SOURCES

Different light sources are now on the market. Incandescence lamps such as quartz-tungsten-halogen (QTH), plasma arc, laser sources of different wavelengths, and light-emitting diodes (LED) have been proposed for light activation. The result is a large spectrum of wavelengths ranging from 380 nm up to 780 nm (between visible and infrared light). Despite the use of filters, a fraction of IR irradiation does not appear to be suppressed in QTH and plasma arc lamps, and hence is emitted during light exposure. The latter may result in a pulpal temperature rise.[5]

LASERS AND ACTIVATION OF THE BLEACHING GEL

Lasers differ from the previously listed systems because they emit one specific wavelength. Moreover, laser light is collimated and coherent. The effect of a laser beam depends on the interaction with the target tissue, as laser light can be reflected by, transmitted through, scattered in and absorbed by the target tissue, material or substance. As absorption is needed for the activation of the bleaching gel, the absorption spectra (ie, the fraction of incident electromagnetic radiation absorbed by the material over a range of frequencies) of the bleaching gel components become important. This also means that it is essential to be aware of the absorption properties of dental tissues and hence the risks associated with laser and light-activated bleaching. Wavelengths with a high absorption coefficient in water and in tooth substance (mineral) will be absorbed at the tooth surface (ie, wavelengths around 3000 nm and 10,000 nm for hydroxyapatite, and starting around 3000 nm for water), where wavelengths in the red and near-infrared range can penetrate biological tissues more easily. Light in the latter spectral range will penetrate deeper into dental tissues, making thermal damage to the pulp more likely.

As a matter of fact, the essential elements of laser light that determine its reaction with matter are the wavelength of the radiant energy (nm) emitted by the laser, the power density of the beam (The measurement of photonic energy relative to time and area of irradiance – W/cm^2), and the temporal characteristics of the beam energy, such as continuous vs pulsed delivery, pulse rate (Hz), and pulse duration. It is more practical to talk about the amount of energy per pulse in Joules (J) (1 J = 1 W x 1 s), rather than the average output power in Watts. A similar concept to power density is energy density, where energy density (J/cm^2) (= fluence) is the amount of energy per unit area . In addition to these factors, which are somewhat inherent to the particular type of laser, there are other variables that relate to differences in the method of energy transfer attributable to instrumentation or delivery systems, such as contact vs non-contact delivery mode, and focused vs unfocused beam.

Besides wavelength, the mechanism of action of the laser depends on the power of the radiation and the pump mode. The pulse mode (continuous wave of pulsed wave) is important for efficacy and safety. At low irradiances and/or energies, laser–tissue interactions are either purely optical or a combination of optical and photochemical or photobiostimulative. When laser power or pulse energy is increased, photothermal interactions become dominant. Pulsed lasers can create very high power densities within a very short time (at present, less than milliseconds).

Thus, before choosing a wavelength for bleaching, it is of the utmost importance to be aware that laser light absorption (wavelength and target substance dependant) is needed for the conversion of the light into heat. It is also the absorption of the respective photons that influences the temperature rise within the bleaching product, the dental hard tissues, or pulp tissues.

LASER BLEACHING

Laser tooth bleaching officially started in 1996, with the FDA approval of the argon laser (480 nm) and the CO_2 laser (10.6 µm) for tooth whitening.[6] However, care has to be taken with the CO_2 laser: the characteristic of this wavelength is thermal, and it is well absorbed in water and hydroxyapatite, which are the primary components of enamel; the thermal effect from the CO_2 laser is favorable for its reaction, but the potentially adverse pulpal responses are a valid concern due to secondary conductive thermal effects. At present, this wavelength is not advised for tooth bleaching.

The objective of laser bleaching is to achieve the ultimate power bleaching while avoiding any adverse effects. The argon laser emits fairly short wavelengths (488 nm) with higher-energy photons; conversely, plasma-arc lamps, halogen lamps, and other heat lamps emit short wavelengths as well as longer invisible infrared wavelengths (750 nm to 1 mm) with lower-energy photons and predictable high thermal character. This high thermal energy can create unfavorable pulpal responses.[6]

Irradiation with the argon laser excites the already unstable and reactive hydrogen peroxide molecule; the energy then is absorbed into all intra- and intermolecular bonds and reaches eigenstate vibrations.[7] The hydrogen peroxide molecule falls apart into different, extremely reactive ionic fragments that swiftly combine with the chromophilic structure of the organic molecules, altering them and producing simpler chemical chains. The result is a visibly whitened tooth surface.

Argon and diode lasers are now commonly used for in-office bleaching treatments. The difficulty with diode lasers is the broad range of wavelengths covered under this name, which makes comparison between different diode wavelengths difficult. Furthermore, output, irradiation time, and the bleaching agent itself are determining parameters[8] and are confusing for the interpretation of the effects of diode laser bleaching. In this respect, higher temperature elevation in the pulp after irradiation with diode lasers than with other lasers or lamps has been reported,[9-12] whereas the increase of the intrapulpal temperature after argon laser irradiation was limited and in the range of other lamps.[5,13,14]

KTP LASER BLEACHING AND THE FEASIBILITY FOR PHOTOBLEACHING

Additional benefits of the use of KTP and argon laser is their feasibility for photobleaching. Photobleaching was described by Bridges et al in 1969.[15] In an investigation of tetracycline staining of rat incisors utilizing 5 tetracycline analogues, they observed that after removal from the animals and upon exposure to daylight, the stained incisors discolored further and at the same time gradually lost their fluorescence under an UV light source. Once the teeth had reached the maximum level of discoloration, they then began to bleach. This loss of discoloration was seen to progress more slowly than the original discoloration. This finding led them to cut in half two human teeth stained by an unstated type of tetracycline and to expose one half of each tooth to an UV light source (360-nm wavelength) for a prolonged, but undisclosed amount of time. They reported that the process of further discoloration and subsequent bleaching was accelerated compared with the rat incisors exposed to daylight. The other halves of the teeth, which were kept in the dark, retained their yellow discoloration and their ability to fluoresce. They suggested that a modification of that method might in the future be used as a treatment for tetracycline-stained teeth. Extracted tetracycline-stained rat, dog and primary human teeth have been observed to darken when exposed to sunlight.[15-17] Further exposure produces a subsequent lightening of the tetracycline stain.[15,17-19]

Tetracycline incorporated into hydroxyapatite, when oxidized by light (photo-oxidation), produces the red quinone product 4α,12α-anhydro–4–oxo–4-dedimethylaminotetracycline (AODTC).[20] Continued photo-oxidation of AODTC photolyses, or bleaches, the red quinone.[21] Efficient wavelengths inducing photo-oxidation are λ = 290 nm and λ = 365 nm, both in the UV range, and λ = 532 nm, which is visible green light.[20] The addition of diluted hydrogen peroxide yields an irreversible bleaching of the red quinone as well.[21]

In addition to the feasibility of photo-oxidation, the KTP laser also induces a photochemical reaction in the bleaching gel, providing a higher intrinsic overall radical yield than thermal activation. The rate at which radicals are generated is higher than with thermal activation. Furthermore, heating is minimized, implying the use of higher energies, so that the overall radical yield per time unit can be further increased.[3]

At present, one laser company has marketed a bleaching gel for the KTP laser: Smartbleach (SBI; Herzele, Belgium). The hydrogen-peroxide-based bleaching gel is mixed with a photosensitizer, rhodamine B dye, resulting in an aqueous gel at high pH (pH 9.5). The activation of the alkaline gel results in the release of hydroxyl and other oxygen free radicals, which can break down various pigmented organic mol-

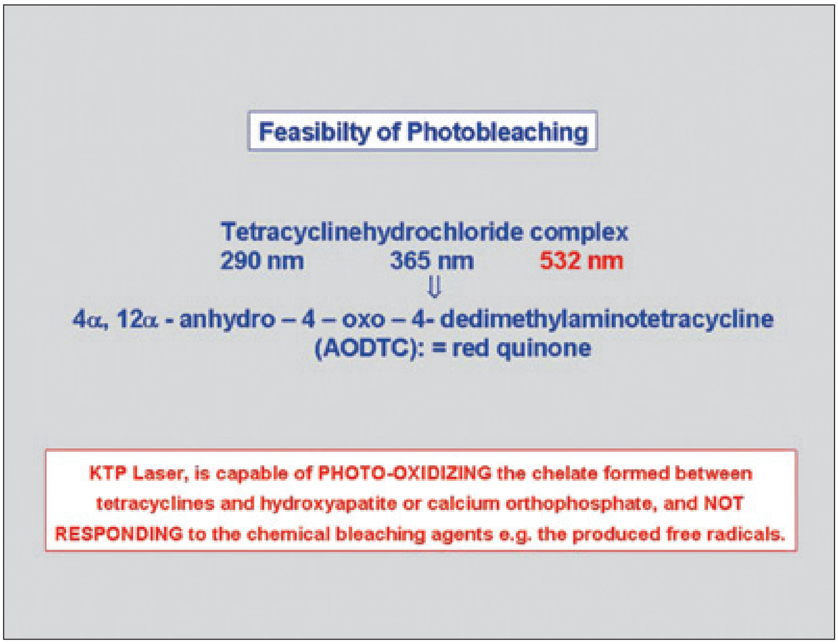

Fig 1 Feasibility of photobleaching of tetracyclines.

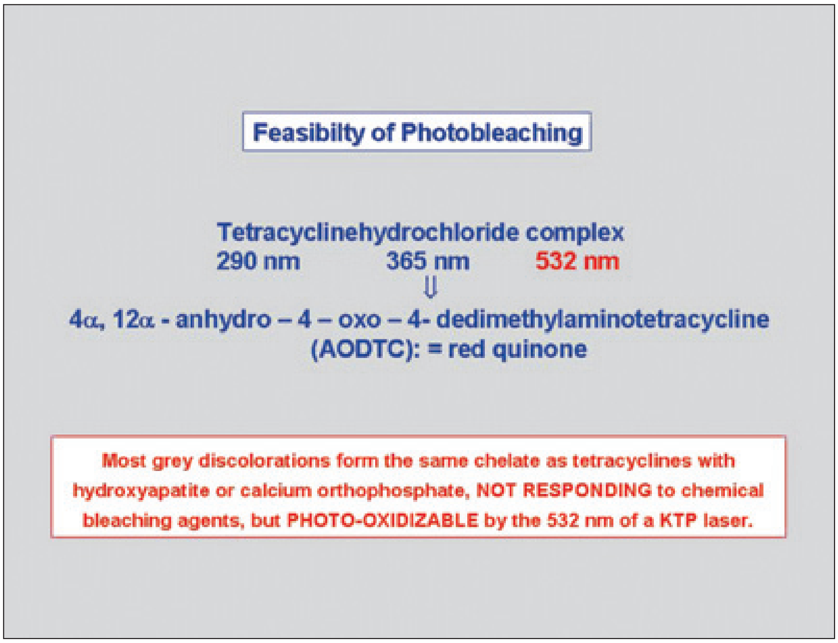

Fig 2 Feasibility of photobleaching of grey discoloration.

ecules. Under these conditions (intense light and alkaline pH), hydroxyl radicals are produced by decomposition of the hydrogen peroxide. These radicals are more reactive than superoxide and other oxygen reactive species.[22] Thus, the activation of the red bleaching gel with the KTP laser under alkaline conditions results in a photocatalytic effect (a limited portion of photothermal activation of the gel and a more expressed portion of photochemical activation). Besides the photocatalytic effect, there is also the feasibility of photobleaching thanks to the specific wavelength. It is clear that the KTP laser is capable of photo-oxidizing the chelate formed between tetracyclines and hydroxyapatite or calcium orthophosphate, which does not re-

Fig 3 Situation before treatment.

Fig 4 Situation before treatment with extremes in the shade guide (VITA B1 and C4) as proposed in Vanderstricht and De Moor.[37]

Fig 5 Teeth 12-21-23 with bleach barrier and bleaching gel.

Fig 6 Clinical situation before laser bleaching.

spond to the free radicals produced by chemical bleaching agents. Most grey discolorations form the same chelate as tetracyclines with hydroxyapatite or calcium orthophosphate. These complexes are also photo-oxidizable by the 532 nm of a KTP laser (Figs 1 and 2). The combination of all these characteristics enables a more profound bleaching of teeth as compared to other bleaching systems. In this respect, research by Walsh and Liu[23] has shown that the whitening effect of photochemical KTP laser bleaching is greater than that of diode laser photothermal bleaching. The efficacy of KTP laser bleaching for the bleaching of heavily tetracycline-discolored teeth has been demonstrated by Vanderstricht and De Moor.[24] When comparing the long-term effect (3 years and more) of KTP-laser bleaching, in-office power bleaching, and in-office bleaching with a highly concentrated hydrogen peroxide gel followed by home bleaching with trays, De Moor and Vanderstricht[25] demonstrated a more enduring bleaching effect (especially for tetracycline cases) for KTP laser bleaching than for other types of in-office bleaching (highly concentrated hydrogen peroxide bleaching gels applied during several sessions and power bleaching with lamps).

KTP LASER BLEACHING, A SAFE PROCEDURE

As already mentioned, higher temperature elevation in the pulp after irradiation with diode lasers than with other lasers or lamps has been reported,[9-12] whereas the increase of the intrapulpal temperature after argon

Fig 7a Clinical situation immediately after laser bleaching (four passes: first and second pass at 1 W for 30 s, third and fourth pass at 3W and 10 s).

Fig 7b Result after 1 month with extremes in the shade guide (VITA B1 and C4) – note that the color of the obliterated tooth now matches with the one of the neighboring teeth (after the end of a bleaching session there is still some post-bleaching effect).

Fig 8 Result after 6 months with stable decoloration.

laser irradiation was limited and in the range of other lamps.[5,13,14] A comparison between temperature elevation in the pulp chamber after irradiation with a diode laser and the KTP laser on tooth surfaces without bleaching gel also demonstrated that the highest temperature elevations were seen when a diode laser was used.[23] For all these systems greater pulpal and surface thermal changes occurred when the appropriate gel was omitted. It is obvious that the absorbing properties of the bleaching gel will also play an important role in influencing both surface and intrapulpal thermal effects.[3,23] Moreover, different gel compositions may result in different thermal changes with the same laser.[26] Nevertheless, when comparing different systems (KTP, LED, diode lasers), only diode lasers remained critical during bleaching treatment even when a layer of bleaching gel was applied on the tooth surface. The temperature rise measured after KTP laser irradiation remained under the critical level of 5.5°C.[8,26]

The pH of bleaching agents determines the rate of reaction of the bleaching process. The more free radicals are produced, the higher the pH.[27] Optimal ionization occurs when hydrogen peroxide is buffered in a range of pH 9.5 to 10.8.[6] Under alkaline conditions, the perhydroxyl ion is produced from hydrogen peroxide.[28] Unfortunately, most commercially available bleaching products are acidic, as this results in a longer shelf-life.[22] In other words, most products are optimized for shelf-life rather than for bleaching purposes.[27] The acidic pH may cause structural changes to dentin and enamel.[29-31] Furthermore, it has also been demonstrated that concentrated 30% solutions of hydrogen peroxide can reduce the microhardness of enamel and dentin. This reduction can be noted with exposure times as short as 5 min for dentin and 15 min for enamel.[32] Surface alteration and change in microhardness were also seen when carbamide peroxide 10% was used.[33,34] As far as the Smart Bleach system is concerned (KTP-laser and Smart Bleach Gel), no adverse effects on the surface morphology have been observed.[26,35]

KTP LASER BLEACHING, AN EXAMPLE OF NON-INVASIVE ESTHETIC DENTISTRY

Patients may present years after a traumatic accident with a single, discolored and intact tooth, which affects the esthetics of the dentition. This discoloration can be the result of obliteration of the pulpal space; the pulpal cavity, in these cases, is filled with dark tertiary dentin, resulting in a tooth with a less translucent appearance. The tooth has gradually decreased in translucency and has become yellow of yellow-brown in color but is still vital.[36]

The most common approach for the whitening or bleaching of this type of teeth is the "walking bleach technique", as external bleaching with conventional bleaching techniques (ie, non-laser bleaching) appears to fail. In this procedure, the bleaching mixture is left in the bur-cut pulp cavity for a few days, and the access cavity is sealed with provisional cement – an obviously endodontic approach. Although discoloration as a result of calcific metamorphosis or obliteration is always mentioned in publications and chapters in text books dealing with the causes of intrinsic staining, such texts neglect to recommended a method for decoloration of this particular type of discoloration. Here and there the term "power whitening" appears; the procedure itself, however, is seldom described for the bleaching of this particular type of teeth or is confined to just one case without follow-up.

In Vanderstricht and De Moor,[37] the working mechanism as well as the clinical procedure of KTP laser bleaching was explained. It was demonstrated that the system used (a KTP laser in association with a red-colored, highly concentrated hydrogen peroxide gel [Smart Bleach gel (SBI]) is currently the only system providing laser bleaching (discoloration of stains on and in tooth substance) with photothermal, photochemical and photocatalytic activation of the bleaching gel. Moreover, this system offered the advantage of performing true photobleaching, meaning that the problem of persisting intense discoloration resistant to the action of the oxygen free radicals such as with tetracyclines and deep greyish discoloration could be solved. Both authors also demonstrated that bleaching of obliterated teeth was possible without the need of intracoronal bleaching. During their follow-up of bleached obliterated incisors, they were able to demonstrate a stable decoloration of at least three years, especially for teeth with a yellow to yellow-brown color. In this way, a non-invasive esthetic solution was provided for this particular type of discoloration. In fact, KTP laser bleaching is the least invasive procedure of minimally invasive dentistry. A representative clinical case is shown in Figs 3 to 8.

REFERENCES

1. Greenwall L. Bleaching techniques in Restorative Dentistry: An Illustrated Guide. Martin Dunitz: London, 2001.
2. Abbot CH. Bleaching discoloured teeth by means of 30 % perhydroxyl and the electric light rays. J Allied Dent Soc 1918;13:259.
3. Verheyen P, Walsh LJ, Wernisch J, Schoop U, Moritz A. Laser-assisted bleaching. In: Mortiz A, Beer F, Goharkay K, Schoop U, Strassl M., Verheyen P, et al (eds). Oral Laser Application. Berlin: Quintessence, 2006:407-448.
4. Buchalla W, Attin T. External bleaching therapy with activation by heat, light or laser – a systematic review. Dent Mater 2007; 23:586-596.
5. Baik JW, Rueggeberg FA, Liewehr FR. Effect of light-enhanced bleaching on in vitro surface and intrapulpal temperature rise. J Esthet Restor Dent 2001;13:370-378.
6. Sun G. The role of lasers in cosmetic dentistry. Dent Clin North Am 2000;44:831-850.
7. Ball P. Bringing down the barriers: Getting chemical reactions to go. In: Designing the Molecular World: Chemistry at the Frontier. Ball P (ed). Princeton University Press: Princeton, 1994:54-82.
8. Zhang C, Wang X, Kinoshita JI, Zhao B, Toko T, Kimura Y, Matsumoto K. Effects of KTP laser irradiation, diode laser, and LED on tooth bleaching: a comparative study. Photomed Laser Surg 2007;25:91-95.
9. Eldeniz AU, Usumez A, Usumez S, Ozturk N. Pulpal temperature rise during light-activated bleaching. J Biomed mater Res B Appl Biomater 2005;72:254-259.
10. Sulieman M, MacDonald E, Rees JS, Addy M. Comparison of three in-office bleaching systems based on 35% hydrogen peroxide with different light activators. Am J Dent 2005;18:194-197.
11. Wetter NU, Barroso MC, Pelino JE. Dental bleaching efficacy with diode laser and LED irradiation: an in vitro study. Lasers Surg Med 2004;35:254-258.
12. Wetter NU, Walverde D, Kato IT, Eduardo CP. Bleaching efficacy of whitening agents activated by xenon lamp and 960-nm diode radiation. Photomed Laser Surg 2004;22:489-493.
13. Jones AH, Diaz-Arnold AM, Vargas MA, Cobb DS. Colorimetric assessment of laser and home bleaching techniques. J Esthet Dent 1999;11:87-94.
14. Luk K, Tam L, Hubert M. Effect of light energy on peroxide tooth bleaching. J Am Dent Assoc 2004;135:194-201.
15. Bridges JB, Owens PDA, Stewart DJ. Tetracycline and teeth – an investigation into five types in the rat. Br Dent J 1969;1:306-310.
16. Walton RE, O'Dell NL,Meyers DL, Lake FT, Shimp RG. External bleaching of tetracycline stained teeth in dogs. J Endod 1982; 8:536-542.
17. Stewart DJ. The effects of tetracyclines upon the dentition. Br J Dermatol 1964;76:374-378.
18. Stewart DJ. Teeth discoloured by tetracycline bleaching following exposure to daylight. Dent Practit 1969;20:309-310.
19. Wallman IS, Hilton HB. Teeth pigmented by tetracycline. Lancet 1962;1:827-829.
20. Lin LC, Pitts DL, Burgess LW. An investigation into feasibility of photobleaching tetracycline-stained teeth. J Endod 1988;14:293-299.
21. Davies AK, McKellar JF, Phillips GD, Reid AG. Photochemical oxidation of tetracycline in aqueous solution. J Chem Soc Perkin Trans 1979;II:369-375.
22. Walsh LJ. Safety issues relating to the use of hydrogen peroxide in dentistry. Aust Dent J 2000;45:257-269.

23. Walsh LJ, Liu JY. Digital image analysis of changes in tooth shade with laser photochemical and photothermal bleaching. ESOLA (European Society for Oral Applications), 2nd Laser Congress, Florence, Italy 2003.
24. Vanderstricht K, De Moor RJG. Laser-assisted bleaching for pronounced discolorations. SOLA (International Society for Oral Applications), 4th Laser Congress, Bruges, Belgium 2007.
25. De Moor RJG, Vanderstricht K. Laser bleaching. Can technology cure disease? Second VBT-Congress (Vlaamse Beroepsvereniging Tandartsen) Dentistry, Science and the Future. Friday 20th March 2009, Antwerp, Belgium.
26. Goharkay K, Schoop U, Wernish J, Hartl S, De Moor R, Moritz A. Frequency doubled neodymium:yttriul-aluminum-garnet and diode laser-activated power bleaching – pH, environmental scanning electron microscopy, and colorimetric in vitro evaluations. Lasers Med Sci 2009;24:339-346.
27. Lee GP, Lee MY, Lum SOY, Poh RSC, Lim KC. Extraradicular diffusion of hydrogen peroxide and pH changes associated with intracoronal bleaching of discoloured teeth using different bleaching agents. Int Endod J 2004;37:500-506.
28. Price BTR, Sedarous M, Hiltz GS. The pH of tooth-whitening products. J Can Dent Assoc 2000;66:421-426.
29. Rotstein I, Dankner E, Goldman A, Heling I, Stabholz A, Zalkind M. Histochemical analysis of dental hard tissues following bleaching. J Endod 1996;22:23-26.
30. Bitter ND, Sanders JL. The effect of four bleaching agents on the enamel surface: a scanning electron microscopic study. Quintessence Int 1993;24:817-824.
31. Ben-Amar A, Liberman R, Gorfil C, Bernstein Y. Effect of mouthguard bleaching on enamel surface. Am J Dent 1995;8:29-32.
32. Lewinstein I, Hirschfeld Z, Stabholz A, Rotstein I. Effect of hydrogen peroxide and sodium perborate on themicrohardness of human enamel and dentin. J Endod 1994;20:61-63.
33. Majeed A, Grobler SR, Moola MH, Rossouw RJ, van Kotze TJ. Effect of four different opalescence tooth-whitening products on enamel microhardness. SADJ 2008;63:282-284.
34. Attin T, Schmidlin PR, Wegehaput F, Wiegand A. Influence of study design on the impact of bleaching agents on dental enamel microhardness: a review. Dent Mater 2009;25:143-157.
35. De Moor RJG, Vanderstricht K. KMO Innovation Project – Province of Eastern Flanders / Belgium – The influence of bleaching agents of two in-office bleaching systems and the Smart Bleach system (KTP laser-activated bleaching) on enamel microhardness. 2007.
36. Rotsein I. Bleaching non-vital teeth. In: Cohen S, Burns RC (eds). Pathways of the pulp, ed 7. Mosby: St Louis, 1998:674.
37. Vanderstricht K, De Moor RJG. KTP-laser asssisted bleaching. J Oral Laser Applic 2009;2:in press.

Contact address: Professor Dr. Roeland De Moor, Department of Operative Dentistry and Endodontology, Ghent University, Ghent University Hospital, Dental School, Ghent Dental Laser Center, De Pintelaan 185 - P8, B-9000 Gent, Belgium. Tel: +32-9-332-4000, Fax: +32-9-332-3851.
e-mail: roeland.demoor@ugent.be