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Potassium-titanyl-phosphate (KTP) Laser and Dental Bleaching. Literature review.

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Abstract: Objective: To determine if dental bleaching with KTP laser is a safe, effective and efficient technique. The use of KTP laser for dental bleaching was only investigated in combination with a high concentration of hydrogen peroxide (35%). The recommended protocol was: for the use of KTP laser at 3W power and an irradiation time of ten seconds, three to four cycles are needed. For a power of 1W and an irradiation time of thirty seconds the number of cycles is three with a maximum of four. Under these conditions KTP laser bleaching was considered not to alter surface morphology, to have no influence on enamel microhardness, to maintain the pulp temperature within normal values, to obtain lighter tooth color which can be maintained for months (no long term studies were conducted). Because the bleaching effect was obtained in a short period of time and maintained for months, KTP laser bleaching was considered an effective and efficient technique. Conclusion: KTP-assisted dental bleaching is a safe, effective and efficient technique when combined with high concentration of hydrogen peroxide. **Keywords:** Dental bleaching, Tooth bleaching, KTP laser, Laser in dentistry.

Láser Potasio-Titanil-Fosfato (KTP) y Blanqueamiento Dental. Revisión narrativa.

Resumen: Objetivo: Determinar si el blanqueamiento dental con láser KTP es una técnica segura, efectiva y eficiente. El uso de láser KTP para blanqueamiento dental fue solo investigado en combinación con una alta concentración de peróxido de hidrógeno (35%). El protocolo recomendado fue: para el uso de láser KTP a 3W de potencia y un tiempo de irradiación de diez segundos, tres a cuatro repeticiones son necesarias. Para una potencia de 1W y un tiempo de irradiación de treinta segundos, el número de repeticiones son tres con un máximo de cuatro veces. Bajo estas condiciones, el blanqueamiento dental con esta técnica no altera la morfología de la superficie dental, no tiene influencia en la microdureza del esmalte, mantiene la temperatura pulpar dentro de valores normales y logra un color más claro el cual puede ser mantenido por meses (no se han realizado estudios a largo plazo). Conclusión: Debido a que, el efecto blanqueador se obtiene en poco tiempo y se mantiene por meses, el blanqueamiento dental con láser KTP se considera una técnica eficiente y efectiva, además de segura. Esto cuando es combinada con peróxido de hidrógeno de concentración alta.

Palabras clave: Blanqueamiento dental, Láser KTP, Láser en odontología.

Introduction.

This review gives an overview of KTP laser used for dental bleaching. Special attention is paid to determine if dental bleaching with KTP laser is a safe, effective and efficient technique as the review objective.

Because today the appearance of teeth is an important part of the smile and the image projected in general, many people have begun to consider the possibility of using dental bleaching. Laser dental bleaching might be one of the most popular options on the market lately, due to its quick results and effectiveness.¹

According to the US Food and Drug Administration (FDA), whitening restores natural tooth color whereas bleaching whitens the teeth beyond their natural color. In other words, whitening refers to the removal of stains on the surface of the tooth with the use of cleaning and polishing agents, whereas bleaching is concerned with doing away with colorants and discolorations in tooth substance by means of oxygen radicals. Unfortunately, the terms "whitening" and "bleaching" are often used interchangeably.²

Dental bleaching is achieved by an oxidation-reduction reaction in which reactive oxygen species and some free radicals released from the dissociation of the bleaching agent attack the long-chained, dark-colored chromophore molecules present in the dental tissues and split them into smaller, less-colored and more diffusible molecules, producing the bleaching effect.² Due to its reactive properties, hydrogen peroxide (HP) is the main active chemical component of most agents used in tooth bleaching therapies. HP can be used in its pure form or as the final product of the dissociation of other bleaching substances, such as sodium perborate and carbamide peroxide.²

The first laser was constructed by exciting a ruby rod with intense pulses of light from a flash light. Using a mixture of helium and neon, Javan³ invented the first actual continuously generating laser ("He-Ne" 633 nm laser). After initial experiments with the ruby laser clinicians began using other lasers, such as argon (Ar; 514 nm) carbon dioxide (CO₂; 10 600 nm), neodymium: yttrium-aluminum-garnet (Nd: YAG; 1064 nm) and erbium (Er: YAG; 2940 nm) lasers.

The laser photoactivation for teeth bleaching purposes began in the early 90's of last century.¹ In 1996 two laser wavelengths had been accepted by the FDA for tooth bleaching: i.e. the argon laser (488/514 nm) and the CO₂ laser (10600 nm).⁴ In 2004, the most commonly used lasers in external tooth bleaching were the diode laser, argon laser, the frequency doubled Nd:YAG or KTP laser, and the combination of the CO₂ laser (to heat the mixture) and Argon laser (to accelerate the process of decomposition of hydrogen peroxide). In 2007 the 980 nm diode laser received FDA approval. It has been found, however, that pulp temperature and tooth sensitivity were associated with the laser diodes technique, so the range from 790 to 980 diode lasers is now also approved. An orientation towards another wavelength appeared recently i.e. KTP (532 nm).

Bleaching with KTP laser.

The KTP laser (potassium-titanyl-phosphate) is a frequency doubled Nd: YAG laser, which releases green visible radiation. Initially, the laser emits a green visible light with a wavelength of 1064 nm and the resulting radiation is filtered in a solid medium made of a KTP crystal system, decreasing the wavelength by half (532 nm), placing it within the electromagnetic spectrum. Green light is selectively absorbed by hemoglobin and melanin, but not by hydroxyapatite or water. The mechanism of bleaching using the KTP laser, patented in 2000⁵, differs from other bleaching systems that use a light source. Its effectiveness is due to the combination of the KTP laser (High Tech Laser: Herzele, Belgium) and the use of Smart Bleach gel (SBI: Herzele, Belgium) which has a reddish color (by the addition of a photosensitizer: sulphorhodamine B) complementary to the green light of KTP laser and containing a high percentage of HP. Once the gel is mixed, the pH goes from 5.5 to 7 and then, when put in contact with the KTP laser, the gel pH increases to values between 9.5-10.5 which favors the appearance of the majority of perhydroxyl radicals [50% more reactive than other oxygen molecules⁶] by ionization of hydrogen peroxide (catalytic effect). Furthermore, the complementary colors of gel and laser (red and green respectively) provide a maximum absorption of light by the gel, which is converted into thermal energy (photothermal effect). The combination of these two effects, photothermal and photocatalytic respectively, induces a more powerful bleaching effect.⁷ In addition to the feasibility of photo-oxidation, KTP laser also induces a photochemical reaction in the bleaching gel providing a higher intrinsic overall radical yield than thermal activation. Furthermore, heating is minimized, implying the use of higher energies so that the overall radical yield per unit time can be further increased.⁸

KTP laser-assisted bleaching shows a great improvement compared to previous techniques.⁹ At present, one laser company has marketed a bleaching gel for the KTP laser i.e. SmartBleachTM (SBI, Herzele, Belgium).¹⁰

The appointment for laser bleaching is approximately 90 minutes long, including the initial preparation and photographs. Before the start of the bleaching appointment, all patients had an initial appointment where their oral health was screened. Also, before the start of the bleaching procedure, patients sign an informed consent form, which informs them about the following: 1) what hydrogen peroxide is and its possible side effects, 2) the bleaching procedure, 3) the fact that in a number of cases more than one session will be needed to achieve a good result and that it is difficult to predict results in advance, 4) the impact of intrinsic colorants on the result and the maintenance of the bleaching result, 5) the fact that filling materials and porcelain cannot be bleached, 6) that a relapse as a function of time due to aging is possible, 7) and that photographs and the patient's background can be used anonymously for research purposes.⁶

The procedure described is the following: Calculus and stains are removed in a session prior to the bleaching appointment. After removing organic substances with pumice (no conventional polishing pastes are used because most of them are oil-based, which may result in the presence of a superficial film on the polished teeth, inhibiting bleaching⁷), a Cheek Retractor[®] (Ivoclar Vivadent: Schaan, Liechtenstein) is then placed, followed by taking photographs. Both extremes in the shade guide (VITA B1 and C4) are included in the first image and a second photograph is taken with the shade guides reproducing the color of the teeth.⁶ Later, a fluid curing resin is used and placed (SmartBlock[®], SBI, Herzele, Belgium) immediately above the dento-gingival line to protect the soft tissues.⁷ The flowable resin is applied in layers, with the first layer covering the cervical aspects of the teeth for approximately 1 mm. After placement of a border 2 cm long (the width of 2 teeth), the resin is photopolymerized. Combined bite block and saliva aspirator (the "expanded duty cotton mouth dry field system", High Tech Laser) is also used. The isolation devices must remain in position and the patient is not permitted to rinse.⁶

The patient, assistant, and dentist performing the laser bleaching procedure must wear protective glasses, because the human eye is extremely sensitive to visible green light. Appropriate protective glasses, goggles or face shields must have an attenuating power of log 4 (OD 4).⁶

The SmartBleach[®] gel needs to be prepared in advance. About 5 ml of peroxide is mixed with the powder to give the desired gel consistency. Once mixed, the gel must be



Figure 1. KTP Laser equipment.

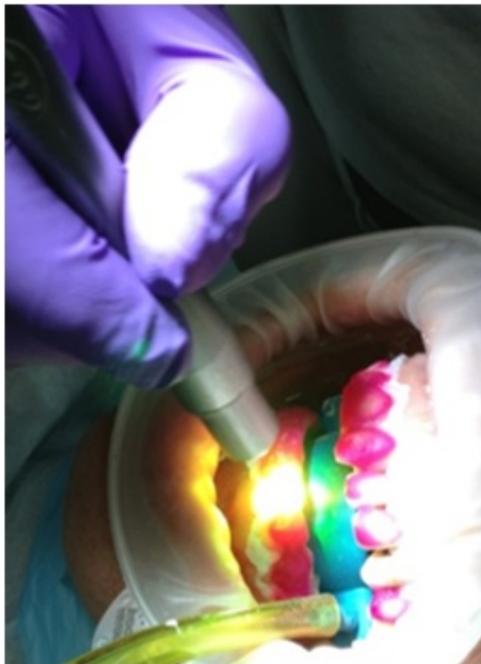


Figure 2. Gel activation with KTP laser.

allowed to stand in its closed container for at least 5 min to allow the carbonate buffer system within the gel to elevate the pH to approximately 9.56. Later, once the SmartBleach® gel is at 35%, it is ready and applied on the external tooth surface with a spatula or a brush in a predetermined sequence.¹¹ Then, the gel is activated with the green KTP laser light (Smart Lite, Deka Frenze, Italy) with a wavelength of 532 nm and power of 1W. Each tooth must be irradiated for 30 seconds with a maximum of four cycles per tooth. A constant distance of 10 mm should be maintained between the tip station light at the distal end of the laser and the outer surface of the tooth (Fig. 2).⁷ The handpiece is moved in a sweeping action across the tooth surface using continuous emission. After irradiation, the gel is left for 10 min on the teeth. Activation and exposure of the gel to the laser beam results in discoloration of the red gel. Therefore, it is important not to apply the gel too thickly. A maximum of 4 applications can be made and the gel is renewed before each exposure to the laser light.⁶

After the last cycle is complete and the teeth are cleaned the final shade can be checked using shade tabs. The two calibrator shades (VITA B1-C4) and the original shades are included in the image to act as reference points. When the bleaching procedure is completed a transparent neutral sodium fluoride gel is applied on the treated surface of the teeth, which is also activated with the KTP laser for 15 seconds to prevent the occurrence of post-treatment hypersensitivity.⁷ The cheek retractors are removed and the result is discussed with the patient. Patients are also instructed not to consume pigmented

foods for 72 hours. An appointment is always made for a control session after 2 weeks. If more than one bleaching appointment is needed, the interval is one month.⁶

Contraindications.

It is very important to first conduct a thorough clinical examination to diagnose the type of staining and discolorations to determine whether there is a contraindication for bleaching treatment.⁹ The main contraindications are leaking restorations, periodontal problems, caries, too many sensitive root necks, and enamel fractures or cracks. Patients are also informed that they

have to stop smoking. Bleaching is not performed in mouths without sufficient oral hygiene, with periodontal problems and untreated carious lesions.⁶ Tooth bleaching is always contraindicated when the structural integrity of the teeth is compromised, e.g., due to amelogenesis or dentinogenesis imperfecta or fluorosis.⁹ Also it is a contraindication: 1) when the patient has unrealistic expectations of the treatment result, 2) when the patient is unable to sit still in the dental chair, and tolerate the required intraoral isolation and retraction devices, 3) when the patient is not compliant with the lifestyle and dietary changes needed to prevent reformation of extrinsic stains, 4) and when the patient is unwilling to have the restorations changed in the teeth to be bleached, after a necessary delay of, at least, two weeks after the bleaching treatment. In addition, there must be a delay of, at least, two weeks to allow oxygen levels in the enamel to return to normal before attempting to bond to the tooth, otherwise oxygen inhibition of resin polymerization will compromise the bonding of the replacement restorations.¹²

Laser regulation and safety.

In various countries, there are a variety of regulatory agencies that control the laser operator and the laser manufacturer, and these standards are strictly enforced. In the USA, the American National Standards Institute provides guidance for the safe use of laser systems by specifically defining control measures for lasers. The Occupational Safety and Health Administration is

primarily concerned with a safe workplace environment, and there are numerous requirements for laser protocols. The Center for Devices and Radiological Health (CDRH) is a bureau within the Food and Drug Administration (FDA) whose purpose is to standardize the manufacture of laser products and to enforce compliance with the Medical Devices Legislation.¹³

Safety is an integral part of providing dental treatment with a laser instrument.¹⁴ Laser devices, instruments and machines vary in their potential for light energy emission from low-powered hand-held or integrated devices, to high-powered units capable of cutting and ablating tissue and materials. The safe use of lasers in dentistry extends to all personnel who might be exposed, either deliberately or by accident, and demands of the lead clinician an approach to their use in order that risk of accidental exposure to laser light is minimized. The scope for regulations extends in similar ways to those imposed on the use of ionising radiation in the dental practice. Laser safety measures in dental surgery are often drawn from the safe approach to the use of lasers in general and other specialties in medicine and surgery.¹⁵

Effect of KTP laser on certain dental aspects.

With KTP laser the temperature increases 2.2 ° C by irradiating with a power of 2 W for 30 seconds per tooth, remaining within the safety margin, set at 5.5 ° C.¹⁶

Also, Vanderstricht, Nammour, and De Moor¹⁷ showed that there were no statistically significant differences when analyzing changes in enamel microhardness after application of KTP laser, diode laser and LED lamps.

About structural changes in the enamel surface it was shown that KTP have no significant differences when analyzing the changes in enamel microhardness.¹⁸ 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.^{19,20} In an investigation²¹ it was demonstrated that laser irradiation of dentin surfaces using KTP laser did not affect the compositional structure of the dentin surface. The mean percentage weights of Ca, K, Mg, Na, P and Ca/P mineral ratios of the dentin were not affected by the laser.

About the efficiency of dental bleaching with KTP laser, in Vanderstricht and De Moor²² 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 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.¹⁰

KTP and argon laser bleaching using Smartbleach system has been shown by electron probe microanalysis to give rapid and deep penetration oxygen molecules into intact tooth structure. In contrast, with home bleaching treatments, the penetration is superficial.¹² In 2009, Kuzekanani and Walsh²³ noted that satisfactory results were obtained with short exposures of time with KTP laser, detecting variations in color from yellow to blue with a single clinical session, confirming them visually using fluorescence ultraviolet.

Discussion.

Consumers around the world have begun to use different utensils for tooth bleaching hoping to get a radiant smile. Next to the use of lamps, laser light may also help in enhancing the bleaching effect and, therefore, in bringing more and more people interested every year.

However, within all the types of laser, KTP laser has shown to be apparently one of the best options for photoactivated-dental bleaching.

A research from Walsh and Liu²⁴ has shown that the bleaching effect of photochemical KTP laser bleaching is greater than diode laser photothermal bleaching and 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, demonstrated that the highest temperature elevations were seen when a diode laser was used.²⁴ 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.^{8,24} Also higher temperature elevations in the pulp have been reported with diode lasers compared to other lasers or lamps.²⁵⁻²⁸ The biggest increase of intrapulpal temperature during bleaching was observed with the use of diode laser (2-14 ° C), exceeding an acceptable limit. The KTP laser produced no lesions in the pulp tissue.²⁹ In another study^{8,19}, 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.

In the 2005 ESOLA Congress (European Society for Oral Laser Applications) two papers related to diode laser whitening were presented. On the one hand Karpodinis *et al.*³⁰ analyze the color changes after tooth whitening, getting the best result with KTP laser followed by the laser diode and the smallest change was obtained with the curing light. Moreover, Nemat and Alimazandarani³¹ show that bleaching performed with hydrogen peroxide

at 35% and diode laser produces a reduction in enamel hardness of 6.16%, while for the bleaching produced by hydrogen peroxide at 38% the reduction was 13%.¹ Therefore, side effects depend on the product used, the concentration of hydrogen peroxide and its pH.

The results of another study³² indicated that successful bleaching was achieved with three light sources: KTP laser, diode laser, and LED when associated with Hi-Lite bleaching gel; however, the 532-nm KTP laser was capable of producing significantly more bleaching than LED or diode laser. Therefore, KTP laser is effective at providing brighter teeth. None of the three light sources employed in this study had a detrimental effect on enamel hardness and during activation of bleaching material, diode laser caused significantly higher intrapulpal temperature rise, which was a disadvantage. On the other hand KTP laser and LED showed pulp-reserving results under the conditions tested. The LED and KTP laser induced a safer pulpal temperature increase when assisted with Hi-Lite bleaching gel.

KTP laser does not appreciably increase temperature. Its photons have high energy that facilitate chemical and photodynamic reactions without damaging either the hard or pulp tissue.²⁹

Data on mechanisms of action and efficacy of laser, and light, and heat-activated dental bleaching are still limited. 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 the bleaching gel) rather than on its own.¹⁰ The KTP laser tooth bleaching is a safe and effective technique if the necessary safety measures are taken. It does not cause changes in the hardness of dental tissues, pulp vitality and adjacent tissues if used appropriately. However, this topic needs more investigation to specify some values such as tooth temperature during the bleaching process, due to the fact that these value measurements are difficult to standardize and only a few experiments have been made. There is still a lot of work to do around dental bleaching with laser.

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