Open Peer Review on Qeios

RESEARCH ARTICLE

Teeth Whitening: Optimization with Violet LEDs

Vitor Hugo Panhoca[1], Viviane Brocca de Souza[2], Simone Aparecida Ferreira[2], Vanderlei Salvador Bagnato[3], Gabriela Dias Rosso dos Santos[4], Marcelo Saito Nogueira[5]

1 Universidade de São Paulo
2 Universidade de São Paulo (USP)
3 Texas A&M University - College Station
4 Faculdade São Leopoldo Mandic
5 University College Cork

Funding: This study was supported by the Embrapii and CEPOF-USP (FAPESP). The authors acknowledge the financial support from the Financier of Studies and Projects (FINEP; grant no. 01.13.0430-00), São Paulo Research Foundation (FAPESP; grant nos. 2013/14001-9 and 2013/07276-1; CEPOF—CEPID Program).

Potential competing interests: No potential competing interests to declare.

Abstract

Introduction: Teeth whitening is an aesthetic treatment performed in dentistry, that is related to the individual's social life. Methods: This is a clinical case report of a patient with dental staining. The presented protocol is innovative due to its reduction in the application time of the whitening gel. The result was evaluated using the Vita Classic color scale. Results: The CBT patient was 58 years old, white and female, the initial measurement of the color of the right maxillary central incisor was performed with scale Vita Classic and presented a measurement of A2 and after tooth whitening with violet light combined with 35% hydrogen peroxide was evaluated with a final measurement of B1. Conclusion: We can consider the device containing violet LEDs combined with whitening gel to be effective for teeth whitening. The protocol applied in this clinical case included a reduction in clinical session time in the office and show no presence of painful sensitivity during and after clinical procedure.

Vitor Hugo Panhóca[1,2], **Viviane Brocca de Souza**[3], **Simone Aparecida Ferreira**[3], **Vanderlei Salvador Bagnato**[1,4], **Gabriela Dias Rosso dos Santos**[2], and **Marcelo Saito Nogueira**[5]

[1] *Biophotonics Laboratory of Institute of Physics of São Carlos, University of São Paulo (USP), São Paulo, Brazil. Postcode: 13560-000.*

[2] *Department of Orofacial Pain, Faculdade Sao Leopoldo Mandic, São Paulo, SP, Brazil. Postcode: 01332-000.*

[3] *Dentistry School, Central Paulista University Center — UNICEP, São Carlos, Brazil. Postcode: 13560-000.*

[4] *Texas A&M University, Texas, United States of America. Postcode: TX 77843.*

[5] *Department of Physics, University College Cork, College Road, Cork, Ireland, Postcode: T12K8AF.*

[*]Corresponding author: Vitor Hugo Panhóca, Institute of Physics of São Carlos, University of São Paulo (USP), São Paulo 13568-695, Brazil. Email: vhpanhoca@ifsc.usp.br

Keywords: Dental bleaching, Hydrogen peroxide, Violet LED, tooth sensitivity.

Introduction

The tooth pigmentation is an aesthetic problem in dentistry that greatly bothers patients who visit a dental office daily. Teeth whitening is an aesthetic treatment performed in dentistry that is related to the individual's social life. Individuals who have teeth whitening obtain greater acceptance in society, significantly influencing their interaction, social and intellectual development[1]. For these reasons, we believe that teeth whitening is not only a treatment with an aesthetic result, but also that it is considered a dental procedure that influences the psychosocial behavior of the individual.

We can classify teeth whitening in three ways in relation to the ways to perform this treatment within modern dentistry based on scientific evidence. In the first way, we can call it home teeth whitening, where the professional follows the procedure remotely, it is performed by the patient himself at home using trays made specifically for this type of treatment concomitantly with the use of whitening gel composed of carbamide peroxide in low concentration. In the second way, we call in-office teeth whitening, where the professional carefully and safely follows the entire procedure and using carbamide peroxide or hydrogen whitening gel in high concentration, accompanied by light or not; and the combination of these two techniques to achieve greater stability of tooth whitening.

For a long time, the teeth whitening technique was based on the use of a gel composed of hydrogen peroxide or carbamide peroxide on the surface of the tooth enamel to obtain the breakdown of the pigments. The pigments impregnate and stain the enamel giving the tooth a yellowish color.[2] These pigments, when fragmented by the action of hydrogen peroxide, begin to reflect light in a modified way, making the teeth whiten. Blue light has been advocated by several researchers as an energy source capable of accelerating this process and, therefore, combines the application of gel and blue light in the teeth whitening performed in the office.[3][4]

Teeth whitening is a procedure that has been widely proven in the dental scientific literature, presenting several protocols for carrying out this procedure.[5][6] Some authors question the use of light as an effective agent in teeth whitening protocols. However, more recent laboratory studies have shown the effect of violet light as a physical agent capable of breaking down pigments that stain bovine teeth and human dental teeth.[7]

There are several teeth whitening protocols recommended by the manufacturer using the Bright Max Whitening system (BMW - MM Optics, São Carlos, SP, Brazil) that uses violet light (LED λ=408±10nm) (Fig. 01) and can use whitening gel or even without applying gel to the tooth surface. The results obtained with this new technique of applying violet light have shown efficacy and advantages presented in the literature, as well as in the protocol that will be presented later in this text with the objective of reducing tooth sensitivity and dental chair time.

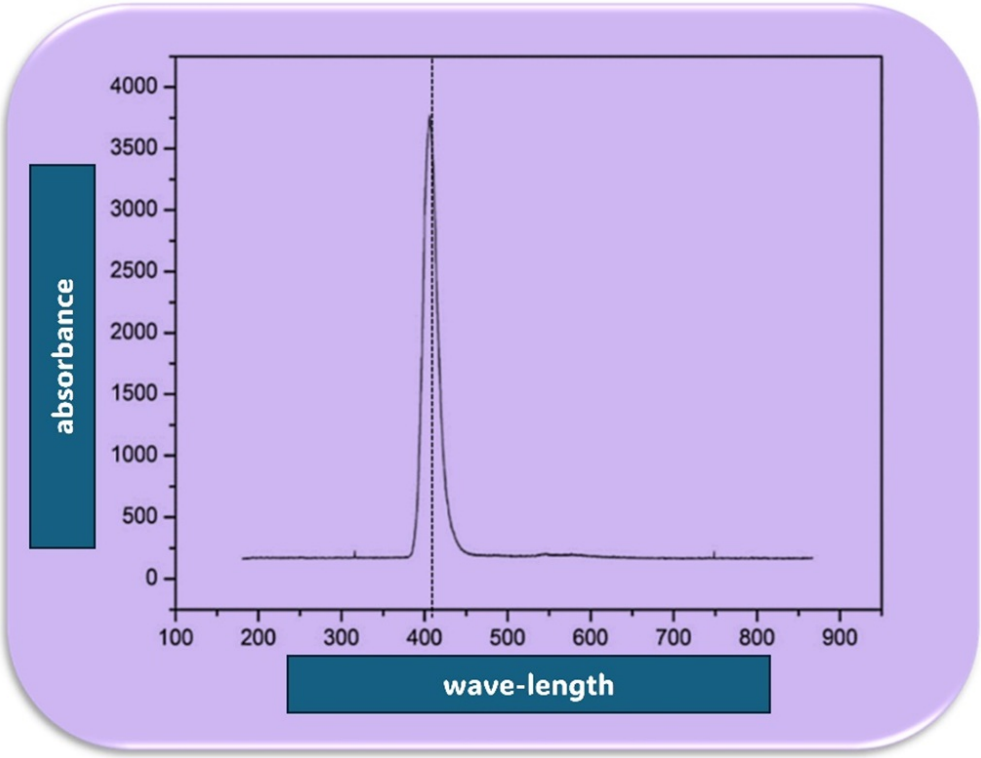

Figure 1. Graph showing the peak absorption of the BMW device containing 4 violet LEDs with wavelength close to 410nm.

Research carried out by the Biphotonic Laboratory of IFSC-USP (Institute of Physics of São Carlos - University of São Paulo) shows the ability of violet light to break down pigments on the surface of bovine teeth, showing the effectiveness of the BMW system in the production of whitening with advantages over conventional techniques.[7][8] In the BMW system, when the gel is not combined, the surface of the tooth enamel is not attacked by substances that can descale the tooth, as with the use of teeth whitening gels.[9]

One of the side effects that causes the most discomfort in the dental office during or after teeth whitening is the dental hypersensitivity caused by the whitening gel and the heating promoted by the blue light.[10][11] Our studies show that the physical action of violet light does not promote dental hypersensitivity when the BMW system is applied with the following recommended protocol. Reports given by patients during and after using the BMW teeth whitening system, who had hypersensitivity, have been made reporting that dental pain sometimes disappears.

Action of violet light on pigments that cause stains on the tooth

To understand the action of violet light on the pigments that stain teeth we must understand how light, molecules and atoms manifest themselves physically in nature not only with a mechanistic physical view, but also with a quantum one. In fact, with this level of observation, our daily intuition must be reassessed. Among the consequences of the quantum nature of molecules is the fact that the spatial distribution of electron charge (spatial occupancy of the electron). Electron orbitals are responsible for chemical bonds (electron clouds), the structure of molecules and, consequently, their various

properties. An important property of this quantum nature is that, like only some of these distributions, changes are only possible when a jump from one configuration to another occurs. These electron transitions are called quantum jumps. The occurrence of these jumps can cause structural changes, modification of reactivity or even interruption of connections causing breakdown of molecular connections.

The quantum jump occurs when electrons are accelerated by an external energy, such as the incidence of a photon on an atom or molecule, this electron excitation moves the electron away from the atomic nucleus which migrates to another orbit different from the previous one. After the excitation of these electrons, they tend to be attracted to the center of the atom's mass and make it a stable element. Basic physics has known about this process for many years. The return of electrons to their orbits closest to their atomic nucleus, if they have not separated from the atom, releases energy packets in the form of photons, described by Gilbert N. Lewis (1926)[12], that cause the emission of light.

The photon is a subatomic particle that has its own physical characteristic. The photon is also recognized as a paradoxical quantum phenomenon[12], as it propagates as a packet of energy and at wavelengths that are related to the colors we see.

By observing the atomic behavior, when energetically animated, we can see that the electrons in the last shells require less energy to jump to the outer shells, and their return creates photons with longer wavelengths. However, electrons in the innermost shells of the atom need more energy to complete their electronic jumps and can even be ejected and transferred to other elements. It would be something like sparks or mini rockets launched by atoms. The light waves that electrons farther from the nucleus produce have higher vibrations and wavelengths, being close to red; Meanwhile, electrons closer to the nucleus emit photons with smaller vibrations and wavelengths, approaching violet, ultraviolet, X-ray, or gamma light—the latter wavelengths are imperceptible to human eyes.

The basic principle of the observation of teeth whitening is related between the combination of these properties known by the physical propagation of light. When light hits the tooth surface and is reflected, nerve cells have the biological ability to recognize the light electrical stimuli that are reflected. These electrical stimuli, i.e. photons are absorbed by nerve terminals located in our retina, nerve cells called cones and rods. These nerve cells process the colors and bring information from this recognition so that brain cognition for these electrical stimuli occurs. This biophysical combination, much studied in several Biophotonics Centers around the world, allows us to understand the effects of violet light (wavelength approximately 408 nm) on pigments in tooth whitening.

The pigments that stain teeth are responsible for absorbing white light and greater amounts of light in the blue electromagnetic spectrum, which promotes greater reflection of light with green and red wavelengths. The combination of reflection of these colors (red, green, and blue) in an unbalanced way makes us feel as if we are looking at a yellowish, unbleached tooth. Therefore, the fundamental chemical role of the whitening gel, or physical through violet light in teeth whitening is that the dental pigment is fragmented. This will promote a greater reflection of blue light from the tooth. Therefore, the color reflection having the mix between the green, red, and blue colors will become more proportional. Causing the observer to observe the whitened tooth surface.

The photon is the smallest particle responsible for the transfer of electromagnetic energy capable of altering the bonds between molecules, such as the pigments that stain the tooth. Violet light has a short wavelength, very close to ultraviolet. Violet light also has a high hertz vibration of its photons, which gives it different energy and absorption characteristics from other wavelength spectra. We can say that violet light has a characteristic of having more energy than other lights in the visible spectrum and being considered within a biological window that does not cause DNA damage in living cells when it is not used at high power or for a prolonged time in living tissues.

Studies have shown the ability of violet light to break down pigments in teeth whitening without the use of gel.[7][13][14] Other studies show that the combination of the use of peroxide combined with violet light showing better effects compared to known techniques of teeth whitening with or without the use of light.[15][16] Violet light is thought to be absorbed by electrons displaced in the electronic clouds that form the molecular bonds of the pigments that stain the tooth. This light energy transferred through photons promotes a transitional change or quantum leap in these electronic clouds, causing π and σ bonds to change to an unstable situation, promoting the dissociation of these molecules.[17] With this theory, the hypothesis is created that as the molecules and the pigment the tooth are broken by violet light, as already detailed in this text, tooth whitening is thus promoted.

Violet light action on the tooth surface

Several published studies show morphological and structural changes because of teeth whitening when applying whitening gels containing peroxides.[18][19] This effect of the gel on the tooth surface is very well described in the literature as tooth decalcification. These studies on tooth decalcification in tooth whitening are performed by electron scanning microscopy (SEM) where the qualitative aspects of superficial changes are evaluated[20][21]. In a recent study carried out by our research group using SEM in the LCE-DEMa-UFSCar laboratory, in which the samples were treated and tested in different situations at a high level, using an EDT[9] detector. After these evaluations and SEM recordings, no damage was identified in samples where only violet light was applied. To understand the superficial aspect of the bovine teeth treated in this study, where the effects of violet light without gel combination were compared with two other groups, where in one group only 35% hydrogen peroxide gel was applied and another was considered control (without treatment), the photos of figures 02 (a, b, c) are presented below.

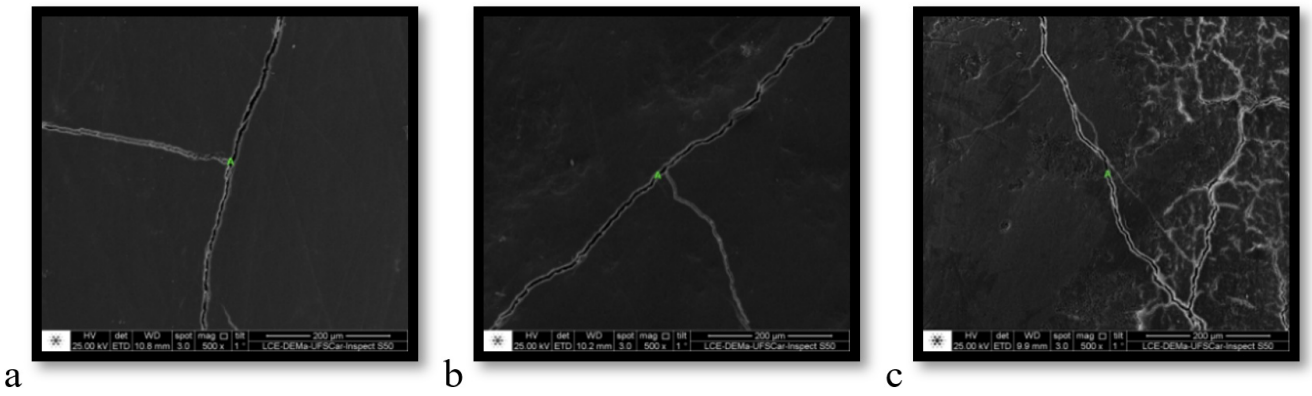

Figure 2. Superficial evaluation using SEM: a-) Control group, no treatment; b-) Photographic protocol of teeth whitening only with light, without whitening gel; c-) Teeth whitening protocol with 35% hydrogen peroxide whitening gel (500x magnification).

The results presented in this study show that there are differences between tooth surfaces when performing teeth whitening using only violet light and whitening gel. It is not possible in this study to quantify the decalcification of the tooth surface, and this may influence a conclusion about this experiment. An important observation was the finding that, apparently, no enamel prism was exposed after the application of light when only violet light is applied, thus reducing the possibility of painful tooth sensitivity due to the surface permeability of the tooth enamel structure. We have found in the literature that tooth decalcification after the use of whitening gel can be compensated in a few hours by the action of saliva or even the application of fluoride.

Methods

In the violet light teeth whitening technique (BMW - MM Optics, São Carlos, SP, Brazil) in the office, the dentist has complete control of the technique, not depending on the patient's collaboration. The patient receives treatment with greater safety, as they are not at risk of gingival irritation due to gel contact, gastric problems due to the ingestion of gel containing peroxide, and dental hypersensitivity due to the use of gel or light. With the BMW system, teeth whitening can be carried out in a practical, fast and effective way, reducing the patient's chair time. The following is a protocol that applies violet light for teeth whitening. The following is a protocol that applies violet light for teeth whitening. This clinical study is a part of an experiment that was carried out in a dental office at the Biophotonics Laboratory of the Physics Institute of São Carlos-University of São Paulo (USP). All procedures were approved by the Ethics Committee of Federal University of São Carlos, Brazil (12/05/2015). This study is registered in the Brazilian Clinical Trials Registry/ Registro Brasileiro de Ensaios Clínicos (ReBEC) under the clinical trial registration number 10859 with the identifiers:

CAAE: Plataforma Brasil (38288114.1.0000.5504)

WHO International Clinical Trials Registry platform:UTN code U1111-1262-5077

Approval number of the clinical research Ethics Committee from Universidade Federal de São Carlos

(UFSCAR):1.037.128

Protocol

The teeth whitening protocol presented in the clinical case below is performed with violet light and clear whitening gel containing 35% hydrogen peroxide. The BMW system was used, and this protocol is indicated mainly for patients with mild or medium dentin hypersensitivity. This protocol is done in just 20 minutes with the intention that the gel will be applied more quickly in contact with the tooth surface. This means that low molecular weight nascent oxygen does not have enough time to penetrate the dental pulp through the dentin tubules and cause pulp damage or even tooth sensitivity. In these cases, violet light was used with the 35% hydrogen peroxide whitening gel for a total of 2 clinical sessions.

Clinical and radiographic examinations were performed, and the patient signed an informed consent form for tooth whitening. Then, prophylaxis was performed using Robinson's brush and pumice paste with water at low rotation. (Figure 3)

Figure 3. Tooth polishing with pumice diluted in water.

To make a comparative assessment of the color of the teeth before and after teeth whitening, the initial recording of the color of the teeth was made using the Vita Classic color scale (Vita Zahnfabrik, H. Rauter GmbH & Co. KG. D-7880 Säckingen, Germany). (Figure 4)

Figure 4. Evaluation of tooth color using the Vitapan Classic scale.

To have better access to the teeth during treatment, the lip retractor was allocated and positioned with a flexible shank or sucking tip between the first molars, allowing mandibular stability throughout the whitening procedure. The protective barrier of gingival tissue was cured with light (Top Dam, FGM Dental Products, Joinvile, SC, Brazil) by photoactivating it for 10-20 seconds with the BMW system device itself.

The application of 35% hydrogen peroxide gel was done for 3 minutes without irradiation with violet light. After that, the irradiation with violet light by LED device with a wavelength of 408nm, containing 4 LEDs, total power of 1400 mW and irradiation of 165 mW/cm². The active tip of the LED device as close as possible to the tooth surface was performed and then activated for 60 seconds, it was repeated 06 times (Cycle=6), and in these 06 irradiations the hydrogen peroxide is maintained on the tooth surface, with a waiting time of 60 seconds between applications (Cycle=6, Active=1min., Passive=1min.). After that, the excess gel is removed and 3 more cycles with violet are performed (Cycle=3, Active=1min., Passive=1min.). Thus, the irradiation with violet light in total is done for 60 seconds to be repeated for 9 times, the total light delivery time was done in 9 minutes and the total time of the clinical session 20 minutes. The violet LED device radiates both arches by vestibular at the same time. The clinical case with this protocol was carried out in 2 sessions with an interval of 7 days between each session. (Figure 5)

Figure 5. Application of violet light with BMW device.

After the end of the irradiation, the gingival barrier is removed with the aid of an exploratory probe. The polishing of the tooth enamel surfaces is performed using a Robson brush with a pumice stone or associated with an extra fine-grained diamond paste (Diamond Excel, FGM Dental Products, Joinvile, SC, Brazil). Written caution guidelines should be given to avoid ingestion with foods and beverages containing dyes.

Results

The tooth whitening of the clinical case shown in this protocol was performed with the application of violet light (BMW system) following the step-by-step instructions shown above. The CBT patient was 58 years old, white and female. In this patient, the initial measurement of the color of the right maxillary central incisor was performed with Vita Classic color scale and presented a measurement of A2 and after tooth whitening with violet light combined with 35% hydrogen peroxide was evaluated with a final measurement of B1. (Figure 6 and 7)

Figure 6. Initial Photo - Clinical Case - CBT Patient

Figure 7. Final Photo - Clinical Case - CBT Patient

Discussion

The protocols shown here are based on research done with the application of violet light through an LED device with a wavelength of 408nm, containing 4 LEDs, total power of 1400 mW and irradiation of 165 mW/cm^2.

Recent research in teeth whitening has sought to improve teeth whitening by minimizing its side effects of dental hypersensitivity and caustic damage to hard and soft tissues in the oral cavity. Several publications of our research group at the Biophotonics Laboratory (IFSC-USP)[15][16][17][22][23][24] with collaborations of researchers from other renowned institutions, place teeth whitening using violet light combined or not with gels containing peroxides in various concentrations as innovative therapy and with fewer side effects at this time within cosmetic dentistry.[25][26]

The application of violet light appears as an innovative reality in tooth whitening with effective results but also as a therapy capable of promoting oral decontamination of the patient. A recent study shows that it was possible to demonstrate that violet light has real applicability in tooth whitening and the potential to be used in oral decontamination.27 Furthermore, violet light has a gingival photocoagulation effect, being a new tool for tooth whitening with the advantage of combining the control and prevention of diseases initiated by microorganisms in the oral cavity and controlling gingival bleeding after its application.[27]

The scientific foundations of photo whitening are based not only on dental science, but also on basic and quantum physics, fully accepted by science. Therefore, the scientific basis of photo whitening is consolidated. In view of consolidated scientific bases, and together with the clinical and scientific knowledge of the dentist, the teeth whitening procedure must be customized and performed to obtain its excellence in each protocol, satisfying the expectations of patients through treatment with evident and proven results in dentistry.

In the current literature on dental whitening, we have described several ways to perform this procedure in the dental office. In this article, we suggest that the main difference in this protocol presented is that it provides satisfactory dental whitening results, as seen in the final photos clinical case. This approach shown here combines a highly concentrated whitening gel and fractional application of violet light in a shorter time, which prevents the penetration of smaller particles of nascent oxygen from reaching greater depths in the hard dental tissue (enamel/dentin) and causing dental sensitivity in the nerve endings found in the dental pulp. Comparing this protocol with other widely used academic and commercial protocols, we believe that the dental tissues are less damaged on the surface and the living tissues present in the dental pulp that are localized more internally.

Long-term follow-up may help assess the durability of the whitening effects and the safety of violet light treatment as performed in this clinical case. This paper only shows one of our clinical cases and we believe that research with a larger “n” should be done to prove our first findings.

Conclusion

We can consider the BMW device as a low to medium power device, which can be combined with gel presenting a tooth whitening effect with a reduction in the time of clinical session in the office, no presence of pain sensitivity during and after the clinical procedure, less physical aggression to the tooth surface, no aggression to soft tissues, the possibility of repeating clinical sessions more frequently without damage to teeth or soft tissues.

Additional Figures

Superficial evaluation using SEM

About the Authors

Vitor Hugo Panhóca DDS, MS, PhD

- Graduated in Dentistry from the Faculty of Dentistry of the Federal University of Rio de Janeiro – RJ, Brazil (UFRJ).
- Specialist in Orthodontics from the Professional Improvement School of the Campineira Association of Dental Surgeons (ACDC – Campinas – SP, Brazil).
- Specialist in Orofacial Pain and Temporomandibular Disorder from the Paulista School of Medicine of the Federal University of São Paulo – SP, Brazil (UNIFESP).
- Guest professor on the Postgraduate course in TMD and Orofacial Pain at Faculdade São Leopoldo Mandic (Campinas-SP, Fortaleza-CE, and São Paulo-SP).
- Former professor of specialization and improvement courses in Orthodontics at APCD-São Carlos-SP, APCD-São José do Rio Preto-SP and ABENO-NAP-UNICSUL - São Paulo-SP, Brazil.
- Master's in Biotechnology from UFSCar. PhD in Biotechnology from UFSCar.
- Post-doctorate in Materials Sciences and Physics at the Physics Institute of São Carlos (University of São Paulo – SP, Brazil).
- Qualified in LASER THERAPY by the Federal Council of Dentistry (Brazil).
- Member of Executive Board Committee World Federation for Laser Dentistry - South American Division (2020-2026).
- Has experience around Physics, with an emphasis on Biophotonics.

- Founding member of the Brazilian Society of Temporomandibular Disorders and Orofacial Pain (SBDOF).
- He has more than 35 articles published in National and International Journals.

Statements and Declarations

Funding

This study was supported by the Embrapii and CEPOF-USP (FAPESP). The authors acknowledge the financial support from the Financier of Studies and Projects (FINEP; grant no. 01.13.0430-00), São Paulo Research Foundation (FAPESP; grant nos. 2013/14001-9 and 2013/07276-1; CEPOF—CEPID Program).

Potential competing interests

No potential competing interests to declare.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgements

This study was supported by the Embrapii and CEPOF-USP (FAPESP). The authors acknowledge the financial support from the Financier of Studies and Projects (FINEP; grant no. 01.13.0430-00), São Paulo Research Foundation (FAPESP; grant nos. 2013/14001-9 and 2013/07276-1; CEPOF—CEPID Program). The authors also acknowledge scientific contributions and helpful advice from Aldo Brugnera Junior e Fátima Aparecida Zanin.

References

1. ^*Malacarne, M. P., Dumer, P. A. P., Louro, R. L., & Pereira, J. (2009). Microabrasion: a simple, safe and effective procedure for the treatment of fluorotic stains. Rev. dental press estét, 6(1), 78-88.*
2. ^*Florez, F. E., Campos, E. A., Oliveira, J. O., Bagnato, V. S., & Panhoca, V. H. (2011). In-office dental bleaching efficacy assessment in function of the light exposure regime by digital colorimetric reflectance spectroscopy. Journal of Dentistry and Oral Hygiene, 3(8), 99-105.*
3. ^*Wetter, N. U., Barroso, M., & Pelino, J. E. (2004). Dental bleaching efficacy with diode laser and LED irradiation: an in vitro study. Lasers in surgery and medicine, 35(4), 254-258.*
4. ^*Marson, F. C., Sensi, L. G., Vieira, L. C. C., & Araújo, E. (2008). Clinical evaluation of in-office dental bleaching treatments with and without the use of light-activation sources. Operative Dentistry, 33(1), 15-22.*
5. ^*Joiner, A. (2006). The bleaching of teeth: a review of the literature. Journal of dentistry, 34(7), 412-419.*

6. ^Parreiras, S. O., Vianna, P., Kossatz, S., Loguercio, A. D., & Reis, A. (2014). Effects of Light Activated In-office Bleaching on Permeability, Microhardness, and Mineral Content of Enamel. Operative dentistry.
7. a, b, cPanhóca, Vitor Hugo, Bruno Pereira de Oliveira, and Vanderlei Salvador Bagnato. (2015) "Dental bleaching efficacy with light application: In vitro study." Photodiagnosis and Photodynamic Therapy 12.3: 357.
8. ^Nogueira, M. S., Panhóca, V. H., & Bagnato, V. S. (2019). Fluorescence spectroscopy analysis of light-induced tooth whitening. In Optical Interactions with Tissue and Cells XXX (Vol. 10876, p. 108761I). International Society for Optics and Photonics.
9. a, bOliveira BP De, Bagnato VS, Panhoca VH (2017) SEM Analysis of a Peroxide Gel Whitening Protocol Associated to Light on Bovine Teeth. JSM Oro Facial Surgeries 2: 2-4.
10. ^Zach, L., & Cohen, G. (1965). Pulp response to externally applied heat. Oral Surgery, Oral Medicine, Oral Pathology, 19(4), 515-530.
11. ^Pohto, M., & Scheinin, A. (1958). Microscopic observations on living dental pulp II. The effect of thermal irritants on the circulation of the pulp in the lower rat incisor. Acta Odontologica, 16(3), 315-327.
12. a, bRigden, J. S., & Rigden, J. S. (2005). Einstein 1905. Harvard University Press.
13. ^Dias A, Lago N, Dandara W, Ferreira R, Furtado GS (2017) Photodiagnosis and Photodynamic Therapy Dental bleaching with the use of violet light only: Reality or Future? Photodiagnosis Photodyn Ther 17: 124-126.
14. ^Zanin F (2016) Recent Advances in Dental Bleaching with Laser and LEDs. Photomed Laser Surg 34: 135-136.)
15. a, bZanin, F., Panhóca, V. H., Brugnera, A. P., Windlin, M. C., & Junior, A. B. (2018). Dental bleaching. the great leap: the use of light without gel. Laser Dentistry: Current Clinical Applications, 467.
16. a, bde Souza Rastelli, A. N., Dias, H. B., Carrera, E. T., de Barros, A. C. P., dos Santos, D. D. L., Panhóca, V. H., & Bagnato, V. S. (2018). Violet LED with low concentration carbamide peroxide for dental bleaching: A case report. Photodiagnosis and photodynamic therapy, 23, 270-272.
17. a, bPanhóca, V. H., Rastelli, A. N., Zanin, F., Bagnato, S. V., & Brugnera Jr, A. (2016). Teeth whitening: a new perspective for Aesthetic Dentistry. Rev assoc paul cir dent, 274-6.)
18. ^Titley, K., Torneck, C. D., & Smith, D. (1988). The effect of concentrated hydrogen peroxide solutions on the surface morphology of human tooth enamel. Journal of endodontics, 14(2), 69-74.
19. ^Cavalli, V., Arrais, C. A. G., Giannini, M., & Ambrosano, G. M. B. (2004). High-concentrated carbamide peroxide bleaching agents effects on enamel surface. Journal of Oral Rehabilitation, 31(2), 155-159.
20. ^Izquierdo-Barba, I., Torres-Rodríguez, C., Matesanz, E., & Vallet-Regí, M. (2015). New approach to determine the morphological and structural changes in the enamel as consequence of dental bleaching. Materials Letters, 141, 302-306.
21. ^Wang, W., Zhu, Y., Li, J., Liao, S., & Ai, H. (2013). Efficacy of cold light bleaching using different bleaching times and their effects on human enamel. Dental materials journal, 32(5), 761-766.
22. ^Panhoca V.H., Oliveira B.P.de, Rastelli A.N.S., Bagnato V.S. (2017) Dental Bleaching Using Violet Light Alone: Clinical Case Report. Dentistry 7: 459.
23. ^Panhóca V.H., Rastelli A.N. de S., Zanin F.A.A., Brugnera Junior A., Bagnato V.S. (2016) A comparative in vitro study of heating intrapulpal applying blue and violet light in tooth whitening. Journal of Japanese Society for Laser Dentistry.

27, 106.

24. ^*Panhóca V.H., Nogueira M.S., Zanin F.A.A., Brugnera A.P., Brugnera Junior A., Bagnato V.S. (2022). Dental Sensitivity and Color Change in Patients Undergoing Dental Bleaching with Application of Violet Light. Oral Health Dental Management, 21, 1-14.*
25. ^*de Oliveira Ribeiro, R. A., Martins, B. V., Dias, M. F., Peruchi, V., Soares, I. P. M., Anselmi, C.,... & de Souza Costa, C. A. (2024). Catalysis-based approaches with biopolymers and violet LED to improve in-office dental bleaching. Lasers in Medical Science, 39(1), 21.*
26. ^*Aidos, M., Marto, C. M., Amaro, I., Cernera, M., Francisco, I., Vale, F.,... & Paula, A. B. (2024). Comparison of in-office and at-home bleaching techniques: An umbrella review of efficacy and post-operative sensitivity. Heliyon.*
27. ^*Panhóca V.H., et al. New Possibilities on the Application of Violet Light in Dentistry Combining Aesthetics and Microbiological Control: Report of Two Clinical Cases. J Dental Health Oral Res. 2022;3(3):1-10.*