Cureus
Part of SPRINGER NATURE

Open Access Review Article

Vital Tooth Bleaching: Whitening Without Harming

Zakaria Karimi [1]

1. Department of Conservative Dentistry, Faculty of Dentistry, Mohammed V University in Rabat, Rabat, MAR

Corresponding author: Zakaria Karimi, karimizakaria1@gmail.com

Review began 10/23/2026
Review ended 10/28/2026
Published 11/03/2026

© **Copyright** 2026
Karimi. This is an open access article distributed under the terms of the Creative Commons Attribution License CC-BY 4.0., which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

DOI: 10.7759/cureus.119075

Abstract

Aesthetic dentistry in general and tooth whitening in particular have experienced increased demand in recent years. Faced with this growing demand, the number of bleaching products and techniques has multiplied. A thorough knowledge of the mechanism of action of dental bleaching treatment, as well as the risks incurred by the application of bleaching products and their activation, is essential to carry out this treatment successfully and avoid possible complications.

The aim of this literature review is to provide insight into the present-day clinical challenges of vital tooth bleaching and to propose a conservative approach that seems to be more efficient with minimal damage.

Categories: Dentistry
Keywords: efficacy, peroxide, safety, tooth bleaching, vital whitening

Introduction And Background

Public demand for aesthetics has increased in the last few decades, particularly for an aesthetic smile, since it has a psychosocial impact and influences the individual's aesthetic self-perception [1]. Consequently, dental bleaching has become the most sought-after treatment by patients in search of aesthetics [2].

Bleaching is of major interest in the treatment of tooth discoloration, which can be of external or internal origin. One of the most common forms of discoloration is the darkening of teeth due to aging [3].

Treatment consists of acting on the color of the tooth by applying products that will act on the molecules of the pigments responsible for the discoloration. Whitening treatment restores teeth to their natural tooth color, whereas bleaching makes teeth lighter than their natural color [4]. Either way, discoloration is achieved by chemical reactions with agents based on peroxide, usually hydrogen peroxide (HP) and carbamide peroxide (CP) [5]. HP reacts directly with color pigments, while CP releases both HP and urea, with HP concentration being approximately one-third of the original CP percentage [6]. As it also contains urea, CP remains in contact with the tooth for longer, with a slower release rate compared to HP [7].

Depending on the concentration of the bleaching agent, the product will have different bleaching guidelines. There are two main categories of professional tooth bleaching techniques: at-home and in-office whitening [8]. The at-home bleaching technique usually involves using low-concentration bleaching products, which are applied through a custom-fitted mouthguard for one to two weeks [9]. The bleaching agent used is usually CP with a concentration of 10-20% [9]. In-office or power bleaching, in turn, is clinically performed by dentists and generally uses a relatively high concentration of HP (25-40%) for shorter time periods. After protection of the soft tissues, the bleaching gel is applied to the teeth with (or without) activation by heat or curing lights to enhance the effects and provide quicker results than home bleaching treatments [10].

This review summarizes the current understanding of vital dental bleaching and discusses factors affecting efficacy and side effects, as well as regulations on the use of bleaching and bleaching products, to propose an approach that seems to be more efficient with the minimum of damage.

Review

Mechanism of tooth bleaching

Although tooth whitening has been studied for decades, the mechanism by which teeth are whitened is currently not fully understood [11]. Most whitening products contain HP as the active agent. HP is a reactive oxygen species that attacks the organic pigmented molecules responsible for tooth discoloration [12]. These large molecules of organic matter known as chromophores possess extended conjugated chains of alternating single or double bonds and often include heteroatoms, carbonyl, and phenyl rings in the conjugated system [13].

During the bleaching process, reactive oxygen species and unstable free radicals released by HP attack

chromophores by an oxidation-reduction reaction, which leads to breaking and changing the pigment molecule configuration and/or size. Such chemical degradations change the optical properties of tooth structure, creating a "whitening effect" [9,14].

The appearance of this effect requires the penetration of peroxide through the different layers of the tooth. Kwon et al. (2012) showed that the diffusion of peroxide through dental tissues occurs via enamel interprismatic spaces and dentinal tubules [15]. On the other hand, Ubaldini et al. (2013) revealed that diffusion is carried out according to the concentration gradient of peroxide and the chemical affinity of dental tissue [16].

It is worth noting that HP may not only target chromophore stains but also interact with the tooth structure and change the chemical composition of enamel and dentin through deproteinization, demineralization, and oxidation [11,17]. Thus, the impact of surface changes contributes to the overall tooth color by decreasing the translucency of enamel and increasing its refractive index, which masks the color of the underlying dentin [18,19].

Kinetics of bleaching and saturation points

At the start of the bleaching process, a high release of free radicals associated with a large amount of chromophores in the dental tissues allows a high oxidation rate and a striking whitening effect. As the applications are repeated, fewer residual pigments remain; therefore, the speed of bleaching decreases drastically [20].

The bleaching process continues until attacking all chromophores; this manifests clinically as perceptible stabilization for the whitening degree, that's the "saturation point." From then on, free radicals begin to act on protein carbon contained in hard dental tissues. With overbleaching, the protein matrix on the enamel and dentine is oxidized, causing damage to the tooth structure [17]. Therefore, the teeth-whitening process must be stopped if there is no improvement in the bleaching effect between application sessions.

Efficacy of bleaching techniques

The bleaching effect depends on various factors such as dental plaque, temperature, pH, tooth isolation, and most importantly, on bleaching gel concentration and the application time. The concentration of peroxide and the duration of application are the two most important factors in bleaching techniques, and they are used differently in each technique [21]. Indeed, the power bleaching technique consists of applying a concentrated HP-containing product (e.g., 25%-40%) for shorter periods, whereas low concentrations of bleaching agents are used in the at-home bleaching technique for a longer period.

In theory, the more concentrated gels would produce a higher bleaching effect [22]. Several studies state that there is no significant difference between the two techniques, despite significant differences in the concentrations used [20,23]. A recent systematic review by de Geus et al. (2025) found that at-home bleaching produced significantly better whitening results [24]. Indeed, although bleaching products at lower concentrations can have less immediate whitening capacity when compared to higher ones, they are often used for an extended duration, which results in similar levels of teeth bleaching [25].

Light Activation

To increase the effectiveness of the in-office bleaching process, different light sources were proposed, such as xenon-halogen light sources, plasma-arc lamps, mercury vapor lamps, and light-emitting diodes (LEDs), as catalysts for the ionization of peroxide in the bleaching gel and to accelerate the bleaching process [4]. Indeed, the light is absorbed by the bleaching gel and converted to heat, which increases the release and penetration of reactive oxygen species, thus increasing the speed of action and faster results [26]. However, the benefits of light activation have been questioned, as many randomized clinical trials have found controversial findings [27-29]. A current systematic review concluded that no type of light activation for in-office bleaching can improve the bleaching efficacy [30]. Furthermore, an increase in the pulp temperature was reported after the use of a light-activated system [31,32].

Laser Tooth Bleaching

Laser light has been introduced in order to achieve better activation of HP within a shorter time period, thereby increasing patient comfort and cooperation [33]. Indeed, laser energy is used to enhance bleaching by direct photo-oxidation of chromophores or by accelerating the release of free radicals within the bleaching gel through photochemical reactions [33]. Different types of lasers have been time-tested for the activation of the bleaching gel, such as diode, erbium-yttrium-aluminum-garnet (Er: YAG), neodymium-doped yttrium aluminum garnet (Nd: YAG), and potassium-titanyl-phosphate (KTP) lasers, of which the KTP lasers have emerged to give promising results [34]. Thus, because it is not absorbed by water or hydroxylapatite, the laser beam (green light) is more efficient in photobleaching and, at the same time, minimizes concurrent damage to the pulp tissue by generating a minimum increase in temperature [35].

However, some studies show that Nd: YAG and high-power diode lasers are the activation methods that produce the highest intrapulpal temperatures [4,36]. These findings are far from unanimous, given that studies on the contribution of laser-assisted bleaching are few and their results are controversial and sometimes contradictory [37].

Safety of tooth bleaching treatment

The application of bleaching products is not completely harmless. Studies show that a variety of undesirable effects can occur after dental bleaching, including morphological alterations in the dental surface, such as depressions, erosion, and porosities, in addition to histochemical alterations [38,39]. Depending on the extent of the alterations, they may cause increased adherence of bacteria and extrinsic staining molecules [6]. Furthermore, changes in enamel micro-hardness, reduction in fracture toughness, and decrease in abrasion resistance were also reported [40]. These alterations are related to the oxidation of enamel and dentin organic matrix that partially lysed and added to demineralization and alteration of the calcium/phosphate ratio that is caused by the low pH of some bleaching agents [16,41,42]. Although remineralization due to saliva may be responsible for a gradual mineral rebuild-up, full repair of the enamel is not established due to degradation of the organic matrix [6]. The damage to the tooth structure (porosity and rugosity) depends on the nature of the product used and its concentration. High concentrations of HP cause the most damage [43].

Besides alterations in hard tissue, tooth hypersensitivity is the most common and disturbing complication to take into consideration when performing bleaching [44]. The pain is related to the inflammatory reaction, which is usually due to the chemical aggression by the peroxide. In effect, several laboratory studies have demonstrated that high concentrations of residual H_2O_2 remain in the dentin and are able to react with the pulp cells [16,45,46]. The rate of H_2O_2 penetration differs between bleaching agents and depends on their concentration and time of application as well as on the thickness of the hard tissue and the presence or absence of restorations [47,48]. The surplus of reactive oxygen species reaches the pulp tissue and causes cell damage [49]. This chemical aggression of the pulp may induce inflammatory reactions characterized by vascular-exudative phenomena and expression of neuropeptides responsible for the perception of pain [49,50]. High concentrations increase inflammatory response and necrosis in the pulp tissue in the short periods after bleaching [51].

Furthermore, the increase in temperature caused by the use of light sources together with the deep penetration of H_2O_2 results in an increase in pulp temperature, which causes tooth sensitivity [52]. The inflammatory process due to thermal aggression of the pulp may be reversible or irreversible depending on the temperature reached and on the duration that the tooth was submitted to heating. Another point that can explain the frequency of dental sensitivity after bleaching is the increase in dentin permeability, which is due to increased porosity and demineralization of dental hard tissue [53,54]. These alterations were directly linked to tooth sensitivity by exaggerated shifts of fluids within dentinal tubules and activation of sensory nerves in the pulp and inner dentin.

Ulceration of the soft tissues is another risk that can be incurred during bleaching. Studies have shown that HP is potentially corrosive to mucous membranes or skin and can cause a burning sensation and tissue damage. Thus, a higher prevalence of gingival irritation was observed after use of higher peroxide concentrations. However, severe mucosal damage can occur if gingival protection is inadequate with high-strength whitening products [55]. In case this occurs, it is recommended to immediately apply water to the area to neutralize the damage. Vitamin E and catalase are also used to arrest the burning effect [55,56].

Furthermore, higher peroxide levels were detected in saliva after bleaching but not up to the estimated toxic dose [57,58]. Del Real García et al. (2019) revealed that HP induced DNA damage [59]. Nevertheless, to date, there's no solid evidence that links tooth bleaching to oral cancer.

Achieving tooth whitening without causing harm

This analysis of factors affecting efficacy leads us to propose a protocol that seems to be more efficient with minimal damage. Prior to every whitening treatment, a thorough interview and clinical examination have to be carried out to avoid side effects, in particular tooth sensitivity. Indeed, the history of sensitivity is the greatest predictor of sensitivity during treatment, and the presence of sensitivity during prophylactic cleaning can indicate the risk of postoperative sensitivity during whitening. Also, it is important to identify any restorations in the anterior sector and explain to the patient that they are likely to require replacement.

If the patient is motivated and able to wear trays at home, whitening with low CP concentration is the recommended bleaching technique that has the most available scientific evidence supporting its efficacy and safety [60]. CP is preferred over HP when applied in a custom-fitted tray because it is more stable, allowing a slow and progressive release [54]. A concentration of 10% is the best compromise between efficiency and safety, which showed similar and more durable results with lower risk and intensity of sensitivity in comparison with more concentrated CP gels [20,30,61-63]. Whitening agents with neutral pH and containing remineralizing agents such as fluoride and calcium are considered to have less damaging effects on enamel [64-66].

For an optimal whitening result, pellicle and plaque must be removed by professional cleaning. This will ensure optimal penetration of free radicals into the teeth. The product is applied at home using a customized tray manufactured by thermoforming from a model taken from a dental impression. The scalloping and trimming of trays following the gingival margin are important to avoid the risk of gingival irritation caused by contact with the product [67]. The use of a reservoir in the tray promotes active whitening gel for longer periods, but it may result in higher intensity of gingival irritation [68].

The product is typically applied after dinner or overnight, with application times ranging from 30 minutes to an entire night. An application time of eight hours provides the best results [69]. The short daytime application period is an alternative method for patients who are unable to wear the trays overnight and prefer daily use. In this case, more frequent replenishment of the whitening gel is envisaged in order to compensate for the dilution of the gel by increased salivary flow and occlusal pressure [70].

After removing the trays and cleaning the residues of whitening gel from the teeth, the use of casein phospho-peptide-amorphous calcium phosphate fluoride (CPP-ACPF) paste is recommended in order to promote remineralization [71]. Potassium nitrate and sodium fluoride as desensitizers are also used widely to prevent and manage tooth sensitivity. These agents may be contained in whitening kits and delivered by using a custom tray during treatment for a 10-minute period before and/or after whitening application [72]. Potassium ions reduce the excitability of the pulpal nerve fibers by preventing their depolarization, and fluoride can occlude exposed dentin tubules by precipitation of calcium fluoride crystals and reducing their fluid flow [73]. It has been suggested that the preoperative application of topical desensitizing gel for two weeks prior to starting the whitening treatment helps to reduce the risk and the intensity of tooth sensitivity [68].

The duration of treatment can range from one to four weeks depending on the dental discoloration and the desired result. In general, satisfactory results can be achieved after two weeks of application; however, extending treatment is often required in cases of important discoloration to reach the saturation point. It has been recommended that the time of use of whitening gel be shortened to reduce side effects such as tooth sensitivity and gingival irritation [74]. Thus, the application of the product should be stopped if no improvement of the bleaching effect between application sessions or in the event of the appearance of sensitivity. In this last case, temporary interruption of whitening and also the use of desensitizing paste before or after whitening is recommended, and the patient can be instructed to alternate application of the product once every two nights or even every three nights in order to achieve the desired result [70].

At the end of treatment, it has been suggested to follow whitening with the use of CPP-ACPF paste for weeks in order to enhance the end result of tooth whitening by increasing the lustre and translucency of the treated enamel and reversing white spots that become more apparent after whitening [71,75].

Conclusions

In spite of the increased demand for dental bleaching, we must not give in to a fad but consider these treatments as real medical treatments and inform our patients in this sense. To avoid not respecting one of the laws of medical practice, which is "first, do no harm," an appropriate clinical examination is necessary to ensure the actual need for the treatment and the absence of risk factors or pathology of concern.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Zakaria Karimi

Acquisition, analysis, or interpretation of data: Zakaria Karimi

Critical review of the manuscript for important intellectual content: Zakaria Karimi

Supervision: Zakaria Karimi

Disclosures

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References

1. Montero J, Gómez-Polo C, Santos JA, Portillo M, Lorenzo MC, Albaladejo A: Contributions of dental colour to the physical attractiveness stereotype. J Oral Rehabil. 2014, 41:768-82. 10.1111/joor.12194
2. Loguercio AD, Maran BM, Hanzen TA, Paula AM, Perdigão J, Reis A: Randomized clinical trials of dental bleaching - compliance with the CONSORT Statement: a systematic review. Braz Oral Res. 2017, 31:e60. 10.1590/1807-3107BOR-2017.vol31.0060
3. Leonard RH Jr: Long-term treatment results with night guard vital bleaching . Compend Contin Educ Dent. 2003, 24:364-74.
4. De Moor RJ, Verheyen J, Diachuk A, et al.: Insight in the chemistry of laser-activated dental bleaching . ScientificWorldJournal. 2015, 2015:650492. 10.1155/2015/650492
5. Hasson H, Ismail AI, Neiva G: Home-based chemically-induced whitening of teeth in adults . Cochrane Database Syst Rev. 2006, CD006202. 10.1002/14651858.CD006202
6. Goldberg M, Grootveld M, Lynch E: Undesirable and adverse effects of tooth-whitening products: a review . Clin Oral Investig. 2010, 14:1-10. 10.1007/s00784-009-0302-4
7. Blanchard D, van Wissen K: Home-based chemically induced whitening (bleaching) of teeth in adults: a summary of a systematic review. Public Health Nurs. 2020, 37:626-7. 10.1111/phn.12713
8. Faus-Matoses V, Palau-Martínez I, Amengual-Lorenzo J, Faus-Matoses I, Faus-Llácer VJ: Bleaching in vital teeth: combined treatment vs in-office treatment. J Clin Exp Dent. 2019, 11:e754-8. 10.4317/jced.56079
9. Joiner A: The bleaching of teeth: a review of the literature . J Dent. 2006, 34:412-9. 10.1016/j.jdent.2006.02.002
10. Marshall K, Berry TG, Woolum J: Teeth whitening: current status. Compend Contin Educ Dent. 2010, 31:486-95.
11. Kwon SR, Wertz PW: Review of the mechanism of tooth whitening . J Esthet Restor Dent. 2015, 27:240-57. 10.1111/jerd.12152
12. Dahl JE, Pallesen U: Tooth bleaching--a critical review of the biological aspects . Crit Rev Oral Biol Med. 2003, 14:292-304. 10.1177/154411130301400406
13. Kwon SR: Tooth whitening: how does it work . Tooth Whitening. Perdigao J (ed): Springer International Publishing, Switzerland; 2016. 21-33. 10.1007/978-3-319-38849-6_2
14. Kihn PW: Vital tooth whitening. Dent Clin North Am. 2007, 51:319-31, viii. 10.1016/j.cden.2006.12.001
15. Kwon SR, Wertz PW, Li Y, Chan DC: Penetration pattern of rhodamine dyes into enamel and dentin: confocal laser microscopy observation. Int J Cosmet Sci. 2012, 34:97-101. 10.1111/j.1468-2494.2011.00688.x
16. Ubaldini AL, Baesso ML, Medina Neto A, Sato F, Bento AC, Pascotto RC: Hydrogen peroxide diffusion dynamics in dental tissues. J Dent Res. 2013, 92:661-5. 10.1177/0022034513488893
17. Sato C, Rodrigues FA, Garcia DM, et al.: Tooth bleaching increases dentinal protease activity . J Dent Res. 2013, 92:187-92. 10.1177/0022034512470831
18. Li Q, Xu BT, Li R, Yu H, Wang YN: Quantitative evaluation of colour regression and mineral content change of bleached teeth. J Dent. 2010, 38:253-60. 10.1016/j.jdent.2009.11.005
19. Ma X, Li R, Sa Y, Liang S, Sun L, Jiang T, Wang Y: Separate contribution of enamel and dentine to overall tooth colour change in tooth bleaching. J Dent. 2011, 39:739-45. 10.1016/j.jdent.2011.08.005
20. de Geus JL, Wambier LM, Boing TF, Loguercio AD, Reis A: At-home bleaching with 10% vs more concentrated carbamide peroxide gels: a systematic review and meta-analysis. Oper Dent. 2018, 43:E210-22. 10.2341/17-222-L
21. Sulieman M, Addy M, MacDonald E, Rees JS: The effect of hydrogen peroxide concentration on the outcome of tooth whitening: an in vitro study. J Dent. 2004, 32:295-9. 10.1016/j.jdent.2004.01.003
22. Torres CR, Zanatta RF, Godoy MM, Borges AB: Influence of bleaching gel peroxide concentration on color and penetration through the tooth structure. J Contemp Dent Pract. 2021, 22:479-83.
23. da Costa JB, McPharlin R, Paravina RD, Ferracane JL: Comparison of at-home and in-office tooth whitening using a novel shade guide. Oper Dent. 2010, 35:381-8. 10.2341/09-344-C
24. de Geus JL, Martins A, Reis A, Rezende M: At-home vs in-office bleaching: an updated systematic review and meta-analysis. Oper Dent. 2025, 50:E47-69. 10.2341/24-078-LIT
25. Aidos M, Marto CM, Amaro I, et al.: Comparison of in-office and at-home bleaching techniques: an umbrella review of efficacy and post-operative sensitivity. Heliyon. 2024, 10:e25833. 10.1016/j.heliyon.2024.e25833
26. Buchalla W, Attin T: External bleaching therapy with activation by heat, light or laser--a systematic review . Dent Mater. 2007, 23:586-96. 10.1016/j.dental.2006.03.018
27. Alomari Q, El Daraa E: A randomized clinical trial of in-office dental bleaching with or without light activation. J Contemp Dent Pract. 2010, 11:E017-24.
28. de Freitas PM, Menezes AN, da Mota AC, et al.: Does the hybrid light source (LED/laser) influence temperature variation on the enamel surface during 35% hydrogen peroxide bleaching? A randomized clinical trial. Quintessence Int. 2016, 47:61-73. 10.3290/j.qi.a34454
29. Bortolatto JF, Trevisan TC, Bernardi PS, et al.: A novel approach for in-office tooth bleaching with 6% H2O2/TiO_N and LED/laser system-a controlled, triple-blinded, randomized clinical trial. Lasers Med Sci. 2016, 31:437-44. 10.1007/s10103-016-1866-2
30. Maran BM, Ziegelmann PK, Burey A, de Paris Matos T, Loguercio AD, Reis A: Different light-activation systems associated with dental bleaching: a systematic review and a network meta-analysis. Clin Oral Investig. 2019, 23:1499-512. 10.1007/s00784-019-02835-x
31. Mondelli RF, Soares AF, Pangrazio EG, Wang L, Ishikiriama SK, Bombonatti JF: Evaluation of temperature increase during in-office bleaching. J Appl Oral Sci. 2016, 24:136-41. 10.1590/1678-775720150154
32. Hahn P, Schondelmaier N, Wolkewitz M, Altenburger MJ, Polydorou O: Efficacy of tooth bleaching with and without light activation and its effect on the pulp temperature: an in vitro study. Odontology. 2013, 101:67-74. 10.1007/s10266-012-0063-4
33. Fekrazad R, Alimazandarani S, Kalhori KA, Assadian H, Mirmohammadi SM: Comparison of laser and power bleaching techniques in tooth color change. J Clin Exp Dent. 2017, 9:e511-5. 10.4317/jced.53435
34. Awati AS, Paul A, Dhaded N, Joshi SB, Lagali-Jirge V: Effectiveness of KTP lasers in tooth bleaching, by

comparing tooth color change after bleaching with KTP, Nd:YAG, Er:YAG, and diode laser system: a systematic review. J Conserv Dent Endod. 2024, 27:685-94. 10.4103/JCDE.JCDE_200_24
35. Zanin F: Recent advances in dental bleaching with laser and LEDs . Photomed Laser Surg. 2016, 34:135-6. 10.1089/pho.2016.4111
36. Michida SM, Passos SP, Marimoto AR, Garakis MC, de Araújo MA: Intrapulpal temperature variation during bleaching with various activation mechanisms. J Appl Oral Sci. 2009, 17:436-9. 10.1590/s1678-77572009000500016
37. Kikly A, Jaâfoura S, Sahtout S: Vital laser-activated teeth bleaching and postoperative sensitivity: a systematic review. J Esthet Restor Dent. 2019, 31:441-50. 10.1111/jerd.12482
38. Chen HP, Chang CH, Liu JK, Chuang SF, Yang JY: Effect of fluoride containing bleaching agents on enamel surface properties. J Dent. 2008, 36:718-25. 10.1016/j.jdent.2008.05.003
39. Briso AL, Gonçalves RS, Costa FB, Gallinari Mde O, Cintra LT, Santos PH: Demineralization and hydrogen peroxide penetration in teeth with incipient lesions. Braz Dent J. 2015, 26:135-40. 10.1590/0103-6440201300225
40. de Oliveira R, Paes Leme AF, Giannini M: Effect of a carbamide peroxide bleaching gel containing calcium or fluoride on human enamel surface microhardness. Braz Dent J. 2005, 16:103-6. 10.1590/s0103-64402005000200003
41. Abouassi T, Wolkewitz M, Hahn P: Effect of carbamide peroxide and hydrogen peroxide on enamel surface: an in vitro study. Clin Oral Investig. 2011, 15:673-80. 10.1007/s00784-010-0439-1
42. Malekipour M, Norouzi Z, Shahlaei S: Effect of remineralizing agents on tooth color after home bleaching . Front Dent. 2019, 16:158-65. 10.18502/fid.v16i3.1586
43. Karimi Z, Saoui H, Sakout M, Abdallaoui F: Effect of vital bleaching on micromorphology of enamel surface: an in vitro study. Prim Dent J. 2021, 10:126-31. 10.1177/2050168420980966
44. Ray DS: Using light to enhance in-office vital bleaching may increase both efficacy and tooth sensitivity . J Am Dent Assoc. 2014, 145:1159-60. 10.14219/jada.2014.76
45. Gökay O, Müjdeci A, Algin E: In vitro peroxide penetration into the pulp chamber from newer bleaching products. Int Endod J. 2005, 38:516-20. 10.1111/j.1365-2591.2005.00979.x
46. Camargo SE, Valera MC, Camargo CH, Gasparoto Mancini MN, Menezes MM: Penetration of 38% hydrogen peroxide into the pulp chamber in bovine and human teeth submitted to office bleach technique. J Endod. 2007, 33:1074-7. 10.1016/j.joen.2007.04.014
47. Vaz MM, Lopes LG, Cardoso PC, et al.: Inflammatory response of human dental pulp to at-home and in-office tooth bleaching. J Appl Oral Sci. 2016, 24:509-17. 10.1590/1678-775720160137
48. de Oliveira Duque CC, Soares DG, Basso FG, Hebling J, de Souza Costa CA: Influence of enamel/dentin thickness on the toxic and esthetic effects of experimental in-office bleaching protocols. Clin Oral Investig. 2017, 21:2509-20. 10.1007/s00784-017-2049-7
49. Roderjan DA, Stanislawczuk R, Hebling J, Costa CA, Reis A, Loguercio AD: Response of human pulps to different in-office bleaching techniques: preliminary findings. Braz Dent J. 2015, 26:242-8. 10.1590/0103-6440201302282
50. Soares DG, Basso FG, Hebling J, de Souza Costa CA: Concentrations of and application protocols for hydrogen peroxide bleaching gels: effects on pulp cell viability and whitening efficacy. J Dent. 2014, 42:185-98. 10.1016/j.jdent.2013.10.021
51. Donato MV, Dos Reis-Prado AH, Abreu LG, et al.: Influence of dental bleaching on the pulp tissue: a systematic review of in vivo studies. Int Endod J. 2024, 57:630-54. 10.1111/iej.14061
52. Santos AE, Bussadori SK, Pinto MM, et al.: Evaluation of in-office tooth whitening treatment with violet LED: protocol for a randomised controlled clinical trial. BMJ Open. 2018, 8:e021414. 10.1136/bmjopen-2017-021414
53. Ogura K, Tanaka R, Shibata Y, Miyazaki T, Hisamitsu H: In vitro demineralization of tooth enamel subjected to two whitening regimens. J Am Dent Assoc. 2013, 144:799-807. 10.14219/jada.archive.2013.0190
54. Luque-Martinez I, Reis A, Schroeder M, Muñoz MA, Loguercio AD, Masterson D, Maia LC: Comparison of efficacy of tray-delivered carbamide and hydrogen peroxide for at-home bleaching: a systematic review and meta-analysis. Clin Oral Investig. 2016, 20:1419-33. 10.1007/s00784-016-1863-7
55. Briso ALF, Rahal V, Gallinari MO, Soares DG, de Souza Costa CA: Complications from the Use of Peroxides . Tooth Whitening-An Evidence-Based Perspective . Perdigao J (ed): Springer International Publishing, Switzerland; 2016. 45-79.
56. Li Y, Greenwall L: Safety issues of tooth whitening using peroxide-based materials . Br Dent J. 2013, 215:29-34. 10.1038/sj.bdj.2013.629
57. Mailart MC, Sakassegawa PA, Torres C, Palo RM, Borges AB: Assessment of peroxide in saliva during and after at-home bleaching with 10% carbamide and hydrogen peroxide gels: a clinical crossover trial. Oper Dent. 2020, 45:368-76. 10.2341/19-127-C
58. Mailart MC, Ferracioli CD, Torres CR, Palo RM, Borges AB: Hydrogen peroxide degradation of bleaching systems with different trays: randomized clinical trial. Am J Dent. 2020, 33:89-94.
59. Del Real García JF, Saldaña-Velasco FR, Sánchez-de la Rosa SV, et al.: In vivo evaluation of the genotoxicity and oxidative damage in individuals exposed to 10% hydrogen peroxide whitening strips. Clin Oral Investig. 2019, 23:3033-46. 10.1007/s00784-018-2716-3
60. American Dental Association: Whitening . (2022). Accessed: May 2025: http://www.ada.org/resources/ada-library/oral-health-topics/whitening.
61. Almeida LCA, Riehl H, Dos Santos PH, Sundfeld MLMM, Briso ALF: Clinical evaluation of the effectiveness of different bleaching therapies in vital teeth. Int J Periodont Rest. 2012, 32:302-9.
62. Matis BA, Cochran MA, Eckert G: Review of the effectiveness of various tooth whitening systems . Oper Dent. 2009, 34:230-5. 10.2341/08-74
63. Tay LY, Kose C, Herrera DR, Reis A, Loguercio AD: Long- term efficacy of in-office and at-home bleaching: a 2-year double-blind randomized clinical trial. Am J Dent. 2012, 25:199-204.
64. Pimenta-Dutra AC, Albuquerque RC, Morgan LS, Pereira GM, Nunes E, Horta MC, Silveira FF: Effect of bleaching agents on enamel surface of bovine teeth: a SEM study. J Clin Exp Dent. 2017, 9:e46-50.

10.4317/jced.53011

65. Coceska E, Gjorgievska E, Coleman NJ, Gabric D, Slipper IJ, Stevanovic M, Nicholson JW: Enamel alteration following tooth bleaching and remineralization. J Microsc. 2016, 262:232-44. 10.1111/jmi.12357
66. Lilaj B, Dauti R, Agis H, et al.: Comparison of bleaching products with up to 6% and with more than 6% hydrogen peroxide: whitening efficacy using BI and WID and side effects - an in vitro study. Front Physiol. 2019, 10:919. 10.3389/fphys.2019.00919
67. L Darriba I, Cabirta Melón P, García Sartal A, Ríos Sousa I, Alonso de la Peña V: Influence of treatment duration on the efficacy of at-home bleaching with daytime application: a randomized clinical trial. Clin Oral Investig. 2019, 23:3229-37. 10.1007/s00784-018-2744-z
68. Perdigão J, Loguércio AD, Reis A, Araújo E: At-Home Tooth Whitening. Tooth Whitening. Springer International Publishing, Switzerland; 2016. 101-43.
69. Cardoso PC, Reis A, Loguercio A, Vieira LC, Baratieri LN: Clinical effectiveness and tooth sensitivity associated with different bleaching times for a 10 percent carbamide peroxide gel. J Am Dent Assoc. 2010, 141:1213-20. 10.14219/jada.archive.2010.0048
70. Sulieman MA: An overview of tooth-bleaching techniques: chemistry, safety and efficacy . Periodontol 2000. 2008, 48:148-69. 10.1111/j.1600-0757.2008.00258.x
71. Milnar FJ: Considering biomodification and remineralization techniques as adjuncts to vital tooth-bleaching regimens. Compend Contin Educ Dent. 2007, 28:234-40.
72. Wang Y, Gao J, Jiang T, Liang S, Zhou Y, Matis BA: Evaluation of the efficacy of potassium nitrate and sodium fluoride as desensitizing agents during tooth bleaching treatment—a systematic review and meta-analysis. J Dent. 2015, 43:913-23. 10.1016/j.jdent.2015.03.015
73. Maran BM, Vochikovski L, de Andrade Hortkoff DR, Stanislawczuk R, Loguercio AD, Reis A: Tooth sensitivity with a desensitizing-containing at-home bleaching gel-a randomized triple-blind clinical trial. J Dent. 2018, 72:64-70. 10.1016/j.jdent.2018.03.006
74. Martos J, Kinalski MA: Combined in-office and take-home bleaching in vital teeth . J Res Dent. 2014, 2:149-53. 10.4103/2321-4619.143599
75. Manton DJ, Bhide R, Hopcraft MS, Reynolds EC: Effect of ozone and tooth mousse on the efficacy of peroxide bleaching. Aust Dent J. 2008, 53:128-32. 10.1111/j.1834-7819.2008.00021.x