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PHOTODYNAMICS THERAPY AS AN ADJUVANT IN DISINFECTING CHANNEL SYSTEM: A LITERATURE REVIEW

TERAPIA FOTODINÂMICA COMO ADJUVANTE NA DESINFECÇÃO DO SISTEMA DE CANAIS RADICULARES: UMA REVISÃO DE LITERATURA

Renata de Matos Cardoso - r94matos@gmail.com
Graduated in Dentistry from the Adventist College of Bahia, Cachoeira, Bahia, Brazil.

Ramon Ribeiro Arruda - ramonr.arruda99@gmail.com
Graduating in Dentistry from the Adventist College of Bahia, Cachoeira, Bahia, Brazil.

Meily de Mello Sousa - meily.sousa@hotmail.com
Master's Degree in Public Health from the Federal University of Rio Grande do Norte. Professor at the Adventist College of Bahia, Cachoeira, Bahia, Brazil.

Juliana Santos de Jesus Azevedo - julianasazevedos@gmail.com
Master's student of the Postgraduate Program in Interactive Processes of Organs and Systems. Salvador, Bahia, Brazil.

Juliana Borges de Lima Dantas - judyborges@gmail.com
Doctoral student of the Graduate Program in Interactive Processes of Organs and Systems. Professor at the Adventist College of Bahia, Cachoeira, Bahia, Brazil.

Júlia dos Santos Vianna Neri - dra.julianeri@gmail..com
Doctorate in Dentistry and Health from the Federal University of Bahia. Professor at the Adventist College of Bahia, Cachoeira, Bahia, Brazil.

Abstract: Introduction: Modern Dentistry aims to minimize invasive procedures and improve the quality and efficiency of care. Photodynamic therapy (PDT) plays an important role in root canals disinfection, without adverse effects or damage to the dental elements and adjacent soft tissues. **Objective:** To discuss the use of PDT in the disinfection of adjuvant root canals to conventional chemical-mechanical preparation. **Materials and Methods:** Narrative literature review carried out through bibliographic collection in SciELO, PubMed, Google Academic and Lilacs data bases, from February to August 2021. The inclusion criteria established were publications on the subject, from 2011 to 2021 and written in English and Portuguese. The crossing of DeCS/MeSH descriptors used the terms “endodontics”, “endodontia”, “fotoquimioterapia”, “photochemotherapy”, “limpeza de canais radiculares”, and “root canal cleaning”, associated with the Boolean operator “AND”. A total of 47 articles were selected for the present study. **Results:** PDT is effective as an adjuvant to endodontic treatment and capable of enhancing the disinfection process of root canals, significantly reducing the amount of microorganisms present in the canals. **Conclusion:** It is observed that PDT can be used as an adjuvant to conventional endodontic treatment without harm to patients. However, more randomized clinical studies are needed in order to establish clinical protocols for the use of PDT as an adjuvant to endodontic treatment, aiming at reducing the failure rates of endodontic therapy and collaborating with the preservation of the dental unit.

Keywords: Endodontics; Photochemotherapy; Antisepsis; Pulp cavity.

1. INTRODUCTION

The main purpose of endodontic treatment is the preservation of dental elements and their root canal systems, through the removal of microorganisms present in endodontic infection, which allows the permanence of the dental unit in the oral cavity and the continuity of its physiological functions. In order to achieve satisfactory results in therapy, the use of working techniques through specific or rotational files associated with chemical substances are fundamental, given their ability to assist in the disinfection of these channels(1). Although endodontic chemical-mechanical preparation techniques have evolved over the years, there are still reports in the literature of failure of endodontic treatment. Through radiographic analysis, it is estimated that the failure is around 11.70% (2), mainly due to mechanical technical failures, during the chemical-mechanical preparation of root canals, associated with the anatomical complexity of the channel systems of the dental units, which consequently interferes with the next stages of endodontic treatment (3).

A therapy that can be used as an adjunct to various dental specialties, including endodontics, in order to control infection, is Photodynamic Therapy (DFT)(3-5), which consists of the use of an appropriate photosensitizer, an apparent light source, and oxygen, generating free radical species and cell death. Light is a factor responsible for exciting the photosensitizer, removing molecules from the biological substrate and interacting through various mechanisms, which results in the production of products responsible for the free radical chain and the oxidation of a range of biomolecules. The photosensitizer, in the ground state, can produce singlet oxygen (O), which is responsible for causing damage to the microorganisms present, such as inactivation itself(4-5).

PDT in antimicrobial use has been shown to be effective when associated with conventional endodontic therapeutic resources (6). This method also aims to assist in the elimination of resistant endodontic mic roorganisms, such as Enterococcus faecalis (7-8). Oliveira et al. (2014), in an in vitro study, reported a significant difference in microbial growth in groups of laser-irradiated bacteria in the presence of a photosensitizer, with a decrease of up to 96.44% of E. faecalis, which demonstrates the reduction in microbial count at the places where PDT was used[9].

In an attempt to optimize the control of infection arising from bacterial resistance, mainly derived from E. Faecalis[10-11], as well as persistent endodontic infections, anatomical complexity of root canals(10), technical failures during mechanical instrumentation, insufficient chemical disinfection and inadequate filling of the channels[12], it is pertinent to study new tools that can contribute to the management and reduction of microorganisms present inside the channel systems. Such tools would increase the success rates in endodontic treatment and contribute to the preservation of the dental unit[10-12].

From the widely known antimicrobial capacity of PDT, and the persistent failure rates of endodontic treatment, a bibliographic survey in the scientific literature on the use of this therapy during endodontic treatment becomes relevant, as a way to assist in the disinfection of the root canal systems of dental units. Therefore, the objective of this narrative literature review was to discuss the use of photodynamic therapy as an adjuvant in endodontic treatment in Dentistry.

2. MATERIALS AND METHODS

This is a narrative literature review, carried out through the collection of scientific articles during the period of February 2021. The electronic databases used were PubMed, Scientific Electronic Library Online - SciELO, LILACS and Google Scholar. The DeCS/MeSH descriptors were used to search for articles, in Portuguese and English, respectively: "endodontics", "endodontics", "photodynamic therapy", "photodynamic therapy", "root channel cleaning" and "root channel cleaning". To refine the search strategy in the respective databases, the Boolean descriptor "AND" was used.

As a criterion for inclusion of articles, they should address the use of GT as an adjuvant in the disinfection of root canals, published between 2011 and 2021, written in English and Portuguese. The exclusion criteria established were works characterized as course completion monographs, books, and scientific articles that did not present their respective abstracts or abstracts on search platforms.

Chart 1 – Descriptor Crossing DeCS/MeSH and number of articles found in tthe respectives databases/repositories.

DATABASE	CROSSING	INITIAL ARTICLES	EXCLUDED ARTICLES	FINAL ARTICLES
GOOGLE SCHOLAR	*Photodynamic Therapy AND Endodontics AND root canal cleaning*	1.712	1.695	31
PUBMED	*Photodynamic Therapy AND Endodontics AND root canal cleaning*	13	8	5
SCIELO	*Endodontics AND Photodynamic Therapy AND root canal cleaning*	10	4	6
LILACS	*Root Canal Cleaning AND Endodontics AND Photodynamic Therapy*	79	74	5
TOTAL				47

Source: Self-Authorship, 2021 (Cachoeira, Bahia, Brazil).

3. READING REVIEW AND DISCUSSION

3.1 CONVENTIONAL ENDODONTIC TREATMENT

The main objectives of root canal treatment are the prevention and treatment of pathologies that affect dental pulp, from the reduction of bacterial infection and the maintenance of root canals and adjacent periodontal tissues [(13)]. It is therefore essential to remove the inflamed tissue infected by groups of bacteria [(14)]. E. *faecalis*, a facultative anaerobic gram-positive bacterium, is the most commonly found microorganism in root canal systems (especially in cases of secondary infections), and has the ability to colonize dentin and dentinal tubules, which makes it difficult to remove them by conventional chemical and mechanical means. Even in the presence of intracanal medication and irrigating solutions, this microorganism has a high potential for intratubular invasion, albeit in nutritional scarcity, in addition to presenting virulence factors[(15)].

Due to the anatomical complexity of the root canal system, with its apical deltas, branches, isthmuses and irregularities, the removal of bacteria becomes a challenge for the dentist, even when conventional methods of endodontic instrumentation and irrigation are performed to the highest technical standards[(1,6)]. The technological advancement of endodontics, from the development and adoption of new technologies and materials, is notorious today and, despite this, endodontic failures and failures are still present in the day-to-day life of dental practice, resulting from poor filling, microinfiltrations, accessory channels, anatomy and shape of the conduits. However, most treatment failures are directly linked to persistent bacterial contamination or proliferation, where hard-to-reach areas are not affected by chemical-mechanical preparation and accommodate substrates composed of tissue debris and bacterial biofilm, which will subsequently negatively affect the prognosis of treatment[(16)].

Epidemiological data indicate that 30% to 50% of the failures of conventional endodontic therapy are related to residual and persistent infections, which require additional strategies to perform disinfection[(17).] Song *et al.* (2011) analyzed the clinical causes of failures in endodontic treatments of 493 roots with periapical lesion after extraction. The apices of the roots were resected and subjected to the application of methylene blue at a concentration of 0.005, during the period of 10 minutes, and then observed by clinical microscope with 26x magnification. The results concluded that the conditions for failures in endodontic therapies were infiltration through the filling material (30.4%); untreated or unmet channel (19.7%); sub-obturation (14.2%); anatomical complexity (8.7%); over-obturation (3.0%); iatrogenic problems (2.8%); apical calculus (1.8%) and fissures and/or cracks (1.2%)[(18)].

During endodontic treatment, disinfectant agents such as sodium hypochlorite (NaOCl), an irrigating solution predominantly used in concentrations ranging from 0.5 to 5.25%, can be used, although other alternative solutions have already been studied. One of these alternatives is chlorhexidine gluconate, because it has an antibacterial effect, substantiveness and lower cytotoxicity compared to sodium hypochlorite[(3,19).]

In addition to the use of irrigating substances, intrachannel drugs are used as antibacterial agents. Such drugs seek to act in the control of infection, neutralization of toxins, act as a physical barrier and control the persistent apical infiltration of fluids into the root canal system. The use of intracanal medication, after biomechanical preparation, has been an alternative in an attempt to eliminate as many remaining bacteria as possible[(20).] In a study conducted by Lynne et al. (2003), the antimicrobial effect of calcium hydroxide in paste and 0.12% chlorhexidine gluconate was evaluated and compared after a 24-hour period in canal dentin infected with E. faecalis. The drugs were tested alone and in combination, at different depths in the dentin tubules infected with the microorganism. The results showed a more pronounced bacterial activity in the formulation that contained only calcium hydroxide[(21).] Therefore, Siqueira et al. (2007) report that the association of calcium hydroxide with chlorhexidine digluconate becomes an effective alternative, because it presents complementary actions to those of calcium hydroxide, acting at a distance, showing residual antimicrobial effects, substance and efficacy also on microorganisms[(22)].

Almyroudi *et al*. (2002) compared the effectiveness of calcium hydroxide, chlorhexidine gel, PerioChip (chlorhexidine tablet formula) and a mixture of chlorhexidine gel with calcium hydroxide as intracanal medication. The substances were tested in three different periods (3 - three, 8 - eight and 14 days), using human teeth previously contaminated by *E. faecalis.* The results show d that calcium hydroxide eliminated microorganisms in 3 (three) and 8 (eight) days, but was not effective in the 14-day group, probably due to a significant drop in pH. Chlorhexidine, in the different formulations, was effective in eliminating *E. faecalis* from dentinal tubules, and a better result was observed with the use of chlorhexidine in gel form(23,24), probably due to the viscosity capacity present in the gel, which gives a longer contact time of chlorhexidine with the surface(24).

Despite the few varieties of irrigating substances and intracanal medications that can be used to aid mechanical preparation, it is evident that the risk of failure of endodontic treatment can be minimized through new tools and methods adjuvant to treatment, such as PDT(25-26).

3.2 PHOTODYNAMIC THERAPY

3.2.1 Photodynamic Therapy History

The first attempts to use GT in humans were made in 1903, in tumors, by Tappenier and Jesionek, in whose abscesses used the eosin dye as a photosensitizer. Despite the beneficial and resolute effects, the use of eosin for the treatment of tumors has not been followed up(27). In 1924, Policard noted that porphyrins could be seen in large concentrations in malignant tumors, being considered non-toxic, but in the presence of visible light and oxygen, they became toxic to cellular tissue(28). In 1976, Weishaupt assumed that singlet oxygen, generated from the energy transfer of the phototherapeutic agent in the excited triplet state to molecular oxygen in the ground state, was the cytotoxic agent responsible for the deactivation of tumor cells(28). In the 1970s, Dougherty et al. reported that GT began to be approved as an alternative for the treatment of malignant cancers or tumors of unknown origins, having been successfully used in the treatment, in addition to showing benefits in reducing the amount of microorganisms in the presence of resistant infections(27).

Currently, GT, in Dentistry, has been used in several specialties, in order to promote minimally invasive, conservative and preservative dentistry. Because it is a minimally invasive technique, the patient is comfortable, there are no associated risks or harms, as well as the absence of side effects, allowing the patient a better quality of life, with good results, both intraoral and extraoral, in a short period of time(28-40).

3.2.2 Photosensitizers most used in Photodynamic Therapy in Endodontics

Different photosensitizers are studied and evaluated in Dentistry with the aim of presenting antimicrobial effects on the tissue. Among them, the two most commonly used can be highlighted: methylene blue (AM) and toluidine blue (AT)[28].

AM is a compound of the phenothiazine family, soluble in water, with low toxicity, being used in various medical and dental areas, with therapeutic purposes at concentrations of 0.005% and 0.01%[29]. In Endodontics, it is the most widely used substance associated with PDT, in an attempt to eliminate resistant bacteria in root canals. Due to its hydrophilic nature, its action is effective in both gram-positive and gram-negative bacteria, which gives its comprehensive character, relevant in the endodontic clinical scenario, where, commonly, the presence of mixed infection is observed[30].

TA is a heterocyclic aromatic dye soluble in water or alcohol, being absorbed intensely in the spectroscopic region of ultraviolet-visible. It is an effective photosensitizing agent in the inactivation of pathogenic organisms such as gram-positive and gram-negative bacteria[30], as well as participates in viral inactivation at a concentration of 1%[31].

It is relevant to discern that, when used at low concentrations, AM and TA do not produce cytotoxic action, which makes their use feasible in endodontic therapy, since the dose required for bacterial death is lower than the dose required to cause cellular cytotoxicity. Because they are dyes, it is essential to completely remove this material from the interior of the channels after the therapy, so as not to offer risks of unwanted pigmentation of the treated dental units. The wavelength with maximum absorption for AM is 670 nm, while for AT, it is 635 nm [30-31].

3.2.3 Characteristics of the light

Devices that produce visible infrared or ultraviolet electromagnetic radiation (lasers) and light emitters (LEDs) are different, but still quite confused. Lasers are different light sources from LEDs, because they have their own aspects, such as monochromaticity, having the same wavelength, collimation, in which the light beams present themselves in the same direction; and coherence, in which photons released in time and space are coincident [32]. On the other hand, LEDs have only monochromaticity. For GT to happen, photons in the visible red band communicate with the AM with a maximum wavelength of 665nm or the AT with wavelength ranging from 660 to 670nm. Both red lasers and red LEDs can be used [33-26].

3.3 PHOTODYNAMIC THERAPY AS ADJUVANT IN ENDODONTIC TREATMENT

The pathogenic microbiota existing in the root canal system during endodontic infection may be present in most dental structures, such as dentinal tubules, isthmus, apical deltas, accessory channels and other structures, causing obstacles to form in the elimination of root biofilm during instrumentation, even with the use of intracanal medications or chemical irrigators(34).

According to Garcez *et al.* (2016), GT emerges as an adjuvant tool in endodontic treatment, which, in addition to reducing bacterial proliferation, helps to reduce direct-acting periapical lesions, acting on endodontic biofilm. Thus, it has the ability to act on the polysaccharides of these colony structures, and is therefore an effective therapeutic resource (35). Microbial reduction in endodontics should occur not only in the main canal, but, ideally, throughout the channel system, such as secondary canals and accessory, apical deltas and also insinside dentinal tubules, because the microbial biofilm is not limited to the main canal(36). Lacerda *et al.* (2014) described that GT should be based on the use of the light source, which is inserted into the channels with the aid of an optical fiber that leads light to the root apex, a photosensitizer at concentrations of 0.005%, 0.01% and 1%, depending on the protocol chosen, inserted throughout the length of the conduits for a period of pre-irradiation ranging from 2.5 to 10 minutes, and oxygen, giving rise to the oxidative reaction, offering an efficient non-toxic medium to reduce the amount of microorganisms present in the root canals(37, 38,43).

An in vitro study by De Oliveira et al. (2015) aimed to evaluate the efficacy of GT and NaOCl in the disinfection of root canals. In this study, the antimicrobial action of GT at different concentrations of NaOCl was examined. For this, single-rooted human lower premolars previously infected with *E. faecalis, Staphylococcus aureus, Pseudomonas aeruginosa, and Candida albicans* were used, and divided into seven groups, namely: Group 1: 1% NaOCl, Group 2: 5.25% NaOCl, Group 3: saline solution + GT, Group In the groups that used GT, BF was used at a concentration of 15 μg/ml, remaining in the conduits for 2 (two) minutes, followed by diode laser irradiation. All samples were collected and sown in culture media to evaluate the permanence or absence of microbial proliferation. In the results, it was observed that NaOCl at a concentration of 5.25% + GT demonstrated a significant decrease in the evolution of microbiological species, as well as 1% NaOCl and 1% NaOCl + GT, which also exhibited similar antimicrobial effects (39). Saline + GT solution did not exhibit the ability to eliminate most microorganisms. These conclusions showed that GT can be useful in aiding in the disinfection of root canals, provided that it is used in conjunction with the chemical substance ((39-33).

Susila *et al.* (2015) proposed in their study to associate alternating irrigation with GT for the disinfection of root canals. For this, they used 80 single-rooted teeth already extracted and inoculated with *S. mutans* and *E. faecalis.* The channels did not obtain previous chemical-mechanical cleaning techniques, so they were only irrigated. The associated irrigating groups were: Group 1: 3% NaOCl + EDTA + GT; Group 2: Saline solution + GT; Group 3: 3% NaOCl + EDTA; Group 4: Saline solution. In the groups that used PDT, BF was used as a photosensitizer at a concentration of 25µg/ml, for a pre-irradiation period of 5 (five) minutes. Then, the conduits were irradiated by diode laser for a period of 30 seconds, with the aid of optical fiber inside the channels and removal of the photosensitizer with NaOCl solution. Dentin chips were removed from the walls of the sample channels and cultivated for the observation of colony formation units (CFU). Group 1 obtained a significantly lower mean CFU compared to the other groups, and a considerable decrease in both bacteria was observed. Group 3 was able to control S. mutans better than group 2, and group 4 had no antimicrobial effect. The protocol proposed in this study has a strong additional effect to the GT technique, and this can be used in primary cases for reliable disinfection of channels and indicated for endodontic failures, given that *E. faecalis* is preponderant in such conditions[(38)].

Ng *et al.* (2011) examined the antimicrobial effects of GT on infected human teeth ex vivo. For this analysis, 52 newly extracted teeth with pulp necrosis and associated periradicular radiolucence were used. Of these, 26 received chemical-mechanical preparation with 17% EDTA + 6% NaOCl (group 1) and 26 teeth received chemical-mechanical preparation with 17% EDTA + 6% NaOCl + GT (group 2). As in the conventional protocol, agitation and final irrigation were performed, in order to apply GT. The channel systems were flooded with AM at a concentration of 50 µg/ml for 5 (five) minutes, foll owed by irradiation with the diode laser, at a wavelength of 665 nm, and the content of the samples was cultured in blood agar. The calculation of the results showed better performance of group 1 when compared to group 2. In the first group, the CFU of the samples were reduced by 82.5%, while the second group showed a reduction in CFU of 49%. Therefore, in this study, PDT did not exhibit a higher efficiency when associated with EDTA and NaOCl [(39)].

The benefits of aggregating PDT in clinical practice in Endodontics are focused on the challenge of performing the maximum elimination of bacteria lodged in contaminated conduits prior to filling [(40).] Clinical research, such as that of Eduardo *et al.* (2015), considers the importance of GT as an aid to traditional endodontic treatment in cases of parendodontic surgery, periapical lesion and antibiotic resistance. This result is relevant within the current scenario of Endodontics, given that some bacteria belonging to the class responsible for endodontic infections are resistant and have a direct influence on bacterial non-recolonization [(4,41)].

Studies that evaluated the use of GT as an adjunct to conventional endodontic treatment are described in Chart 1.

Table 1– Técnicas/protocolos da TFD empregados de forma adjuvante ao tratamento endodôntico.

Author, year and country	**Type of study**	**Objective**	**Metodology**	**Results**	**Conclusion**
Asnaashari *et al.* 2016, Iran.[42]	*In vivo*	Compare the use of 2.5% NaOCL + TFD and 2.5% NaOCL + Diode Laser in a group of microorganisms.	Microorganisms tested and irrigating solution / therapy used: E. faecalis, F. nucleatum and P. gingivalis/ Group 1: 2.5% NaOCl + GT; Group 2: 2.5% NaOCl + Diode Laser. Photo sensitizing / concentration / pre-irradiation time: AM at 0.5 ml at 0.01% for 5 (five) minutes. Light source/wavelength/power/Iradiation time/ teeth: Diode laser, 810 nm, 0.2W/cm2 Group 1: 40s; Group 2: 30s with the use of optical fiber 20 teeth in need of retreatment.	CFU/ml values were significantly reduced in the group submitted to the GT process and in the group submitted to diode laser.	GT and 810 nm diode laser are effective methods for disinfecting root canals.
De Oliveira *et al.* 2015, Brazil.[34]	*In vitro*	Observe the efficacy of NaOCl at different concentrations and GT against microorganisms.	Microorganisms and irrigating solution: E. faecalis, P. aeruginosa, S. aureus and C. albicans. Group 1: 1% NaOCl; Group 2: 5.25% NaOCl; Group 3: saline + GT; Group 4: 1% NaOCl + GT; Group 5: 5.25% NaOCl + GT; Group 6: positive control; Group 7: negative control. Photosensitizer/concentration/pre-irradiation time: AM at a concentration of 15 µg/mL for 2 (two) minutes. Light source/wavelength/power/Iradiation time/tooth: Diode laser at 660 nm, 100 mW, 1.5 minutes with the use of optical fiber in 70 single-rooted lower premolars.	NaOCl at 5.25% + GT resulted in a larger number of the sample without microbial growth. 1% NaOCl and 1% NaOCl + GT showed similar antimicrobial effects. Saline + GT did not eliminate microorganisms significantly.	The combination of 5.25% NaOCl with PDT was the most effective treatment against microorganisms during endodontic disinfection. This result suggests that PDT may be useful to improve root canal disinfection.
Soares *et al.* 2016, Brazil.[43]	*In vitro*	Observe the results of the use of NaOCl at 5.25% + EDTAa 17% in *E. faecalis*	Microorganisms and irrigating solution: E. faecalis/ NaOCl 5.25% + EDTA 17%. Photosensitizer/concentration/pre-irradiation time: AM at a concentration of 1.6 µM/ml for a period of 2.5 minutes. Light source/wavelength/power/Irradiation time/teeth: Laser diode of 660 nm, 40 mW, 2.5 minutes with the use of fiber optics in 40 canines.	The technique applied in endodontic treatment, associated with two sessions of GT, improved in reducing the bacterial load and no resistant microorganism was found in the samples.	PDT promoted an immediate and progressive reduction in bacterial load. This is a strategy for the relevant disinfection of root canals contaminated by *E. faecalis.*

Susila *et al.* 2016, India.[38]	*In vitro*	Compare the efficacy of the use of EDTA and GT in *S. mutans* and *E. faecalis*	Microorganisms/irrigating solution: S. mutans and E. faecalis/ Group 1: 3% NaOCl + EDTA + GT; Group 2: Saline solution + GT; Group 3: 3% NaOCl + EDTA; Group 4: Saline solution. Photosensitizer/concentration/pre-irradiation time: AM at a concentration of 25 µg/ml for 5 (five) minutes. Light source/wavelength/power/Iradiation time/tooth: Diode laser at 665 nm, 1W/cm2, for 30 seconds with the use of optical fiber in 80 single-rooted teeth.	Group 1 with E. faecalis had a significantly lower mean CFU than all other groups (p = 0.001).	An additional effect of the combined application of antimicrobial irrigators and GT could be observed in the eradication of common endodontic pathogens.
Juric *et al.* 2014, Croatia.[44]	*In vivo*	To evaluate the use of NaOCl, EDTA and GT in teeth in need of retreatment.	Irrigating solution: 2.5% NaOCl + 17% EDTA + saline solution + GT. Photosensitizer/concentration/pre-irradiation time: Phenothiazine chloride at a concentration of 10 mg/mL, for 2 (two) minutes. Light source/wavelength/power/Iradiation time/tooth: Diode laser at 660 nm, 100mW, for 1 (one) minute with the use of optical fiber in 21 single-rooted teeth.	14 species of bacteria were initially isolated from the canals. Although endodontic retreatment has significantly reduced the number of bacterial species (p <0.001), the combination of endodontic treatment and GT was statistically more effective (p <0.001).	PDT together with the conventional root canal preparation led to a significant reduction in the number of CFUs and the elimination of bacteria. The combination of chemical-mechanical cleaning and GT was more successful in eliminating species of gram-positive and gram-negative bacteria, facultative anaerobes and obligate anaerobes, compared to isolated chemical-mechanical cleaning.
Rios *et al.* 2011, United States.[45]	*In vitro*	Avaliar os resultados do uso de NaOCl, EDTA e TFD contra *E. faecalis.*	Microorganisms/irrigating solution: E. faecalis/ 6% NaOCl + 17% EDTA + GT. Photosensitizer/concentration/pre-irradiation time: AT at a concentration of 0.25 ml for 30 seconds. Light source / wavelength / Irradiation time / teeth: LED at 628 nm for 30 seconds in single-rooted teeth.	The bacterial survival rate of teeth treated with NaOCl and GT (0.1%) was significantly lower (p<0.005) than when treated with NaOCl alone.	PDT has the potential to be used as an adjunct antimicrobial procedure in conventional endodontic therapy.

Xhevdet *et al.* 2014, Slovenia.[47]	*In vitro*	To verify the results of NaOCl and GT in *E. faecalis* and *C. albicans*.	Microorganisms and irrigating solution: E. faecalis and C. albicans/ 2.5% NaOCl + GT. Photo sensitizing / concentration / pre-irradiation time: Phenothiazine chloride at 10 mg/mL for 1, 3 and 5 (five) min. Light source / wavelength / power / Irradiation time / teeth: Diode laser at 660 nm. 100 mW/cm2, / 1 (one), 3 (three) and 5 (five) minutes in 156 single-rooted teeth.	The laser further reduced the set of remaining microorganisms. So far, PDT has proven to be an efficient adjuvant therapy	PDT proved to be an appropriate method for channel disinfection, obtaining results similar to irrigation with NaOCl.
Ng *et al.* 2011, United States.[39]	*Ex vivo*	Investigate the action of NaOCl, EDTA and GT in newly extracted teeth with pulp necrosis and periapical lesion.	Teeth and irrigating solution: 52 single and multiradicular teeth with newly extracted pulp necrosis and periapical lesion. Group 1: 6% NaOCl + 17% EDTA; Group 2: 6% NaOCl + 17% EDTA + GT. Photo sensitizing / concentration / pre-irradiation time: AM at a concentration of 50 µg/ml for 5 (five) minutes. Light source / wavelength / power / Irradiation time / teeth: Diode laser at 665 nm, 100 mW/cm2 for 5 (five) minutes, in 52 teeth.	Group 1 had higher levels of infection compared to the channels in group 2 ($p<0.0001$).	GT significantly reduces residual bacteria within the root canal system with the use of appropriate wavelength light to generate singlet oxygen and free radicals.
Souza *et al.* 2010, Brazil.[46]	*In vitro*	Investigar os efeitos antibacterianos da TFD com AM e AT em canais contaminados com *E. Faecalis.* Investigate the antibacterial effects of GT with AM and TA in channels contaminated with *E. Faecalis.*	Microorganisms / teeth and irrigating solution: E. faecalis / 70 single-rooted teeth / Group 1: GT and AM + NaOCl 2.5%, Group 2: GT and AT + NaOCl 2.5%, Group 3: GT and AM + Sodium Chloride (NaCl) 0.85%, Group 4: GT and AT + NaCl 0.85%. Photo sensitizing / concentration / pre-irradiation time: AM or AT at a concentration of 15 µg/mL for 2 (two) minutes. Light source / wavelength / power / Irradiation time: Diode laser at 660 nm, 40 mW for 4 (four) minutes.	NaOCl and NaCl, in isolation with instrumentation, substantially reduced the bacterial count. NaOCl was considerably more effective than NaCl. This difference persisted after PDT. Regardless of the photosensitizer used, no significant differences were observed between the two photosensitizers ($p>0.05$).	PDT with BF or TA can have a significant additional effect, however, when related and compared, they do not indicate significant differences between them in relation to intracanal disinfection. Further adjustments are suggested in the GT protocol to increase predictability in bacterial elimination.

Source: Self-authorship, 2021 (Cachoeira, Bahia, Brazil).
Subtitle: NaOCl: Sodium Hypoclorite; TB: Toluidine Blue; AM: de Methylene Blue; TFD: Photodynamic Therapy; UFC: Colony Formation Units; W: Watt; nm: Nanometer; µg: Micrograms; mW: Microwatt;NaCl: Sodium Chloride

4. CONCLUSION

In accordance with the studies included in this narrative literature review, it can be suggested that PDT is a promising adjuvant alternative in conventional endodontic treatment, as it may collaborate with intracanal microbiological decontamination soon after chemical-mechanical preparation. Among the benefits, it is possible to highlight its easy application, a selective characteristic, the fact that it avoids the promotion of bacterial resistance, low cost and non-association with unwanted side effects. Therefore, its use can increase the success rates in endodontic treatment and long-term preservation of the dental unit. However, it is essential to conduct more randomized clinical trials that clarify and define safe protocols for GT in endodontics, in order to enable its use in the endodontic clinical routine.

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