# The Effect of Photodynamic Therapy in Root Canal Disinfection: A Systematic Review

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## Abstract

**Introduction:** Effective root canal disinfection is a fundamental component of successful root canal treatment. Photodynamic therapy (PDT) has been proposed as a new adjunctive method for additional disinfection of the root canal system with the possibility of improved treatment outcomes. The aim of this systematic review was to investigate the effect of PDT on bacterial load reduction during root canal disinfection. **Methods:** Two reviewers independently conducted a comprehensive literature search using a combination of medical subject heading terms and key words to identify studies relevant to the Population Intervention Control Outcome question. The selection of articles for inclusion was performed in 2 phases based on predetermined eligibility criteria according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Inter-reviewer agreement for each phase was recorded. The effect of PDT on bacterial load reduction during root canal disinfection was evaluated as the primary outcome variable during data extraction. **Results:** The literature search provided 57 titles and abstracts. Three articles met the inclusion criteria and were selected for this systematic review. The reasons for study exclusion in each phase were recorded. Because of the heterogeneity in clinical indications and PDT protocols among the included studies, a meta-analysis could not be performed. All included studies showed a positive effect of PDT in the reduction of microbial load in root canal treatment ranging from 91.3%–100%. **Conclusions:** Limited clinical information is currently available on the use of PDT in root canal disinfection. If supported by future clinical research, PDT may have efficacy for additional root canal disinfection, especially in the presence of multi–drug-resistant bacteria. *(J Endod 2014;40:891–898)*

## Key Words

Antibacterial, bacteria reduction, light-activated disinfection, photodynamic therapy, reactive oxygen species, root canal disinfection

Effective root canal disinfection is undoubtedly a fundamental component of successful root canal treatment. Contemporary techniques include the mechanical debridement and shaping of the root canal system with emphasis on various nickel-titanium (NiTi) rotary systems, intracanal irrigation with antimicrobial/tissue dissolving agents, and interappointment dressings. However, several studies have reported that rotary and hand instruments are equally effective in bacteria reduction, and despite the improved efficiency of NiTi systems, there is no difference in antimicrobial reduction (1, 2). Regarding chemotherapeutic agents, sodium hypochlorite (NaOCl) has been considered as the "gold standard" because of its antibacterial and tissue dissolution properties (3, 4). Nevertheless, numerous studies have verified that complete elimination of bacteria from the root canal system cannot be consistently achieved with any of the currently used techniques and combinations (1, 5–9).

In search of new methods to provide additional disinfection for the root canal system and presumably improve treatment outcome, novel techniques including various laser wavelengths (10); hydraulic (eg, Endo-Vac; SybronEndo Corporation, Orange, CA) (11), sonic (12), and ultrasonic (13, 14) irrigation; and gaseous ozone (15) and photodynamic therapy (PDT) (16) have been proposed in the literature. PDT is an antimicrobial strategy defined as "light induced inactivation of cells, microorganisms and molecules" (17). In principle, it uses a nontoxic photosensitizer that is selectively absorbed in a target tissue and a low-intensity light source. Upon photo-induced activation of the photosensitizer, in the presence of oxygen, a series of reactions produce free radicals and singlet oxygen molecules leading to bacterial eradication. Singlet oxygen diffuses to a distance of approximately 100 nm with a half-life of <0.04 microseconds (18). The photodynamic effect or the extent of tissue/cell damage depends on the type, dose, incubation time, and localization of the photosensitizer; the availability of oxygen; the wavelength of light (nm); the light power density measured in $mW/cm^2$; and the light energy fluency. Of all the PDT dosimetry parameters, fluency appears to cause some confusion. Some authors use the cross-sectional area of the light source, whereas others use a light effect on a determined area. In either case, fluency represents the rate of deposited energy in a specified area and is expressed in $J/cm^2$. Because of its high antibacterial potential, PDT has been suggested as an adjunct to conventional endodontic disinfection protocols.

Currently, the use of PDT in endodontic therapy has been tested in terms of bacterial load reduction *in vivo* (16, 19, 20) as well as *in vitro* (21, 22) and *ex vivo* (23) and has shown promising results. A recent systematic review of PDT against *Enterococcus faecalis* provides a direct comparison of these studies (24). Despite recent research efforts to study the effect of PDT on the disinfection of the root canal system, no effort has been made to evaluate the efficacy of this approach by means of a system-

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atic review of the literature. Thus, the aim of this systematic review was to investigate the effect of PDT on bacteria load reduction during root canal disinfection.

## Materials and Methods

### Population Intervention Control Outcome Question

To address the aim of this systematic review, the following question was constructed based on the Population Intervention Control Outcome (PICO) principle: "For patients undergoing root canal treatment, does the use of PDT compared with conventional chemomechanical techniques alone further reduce the bacterial load?"

### Search Strategy

A search was conducted for articles related to the PICO question, which were published from January 2000 to June 2013. The literature search included an electronic search of the PubMed database of the US National Library of Medicine and the Cochrane Central Register of Controlled Trials (CENTRAL) using the following combination of medical subject heading terms and key words: "photodynamic" OR "light activated disinfection" OR "photodynamic therapy" OR "photo-activated disinfection" AND "endodontics" OR "photodynamic therapy endodontics" OR "light activated disinfection root canal" OR "photodynamic therapy endodontic" OR "light activated disinfection endodontics" OR "photo-activated disinfection endodontics." Reference lists from identified articles or literature reviews were also searched to identify other potentially relevant articles.

### Study Selection and Quality Assessment

The titles and abstracts of all articles identified from the electronic search were screened independently and in duplicate by 2 reviewers. The review process was performed to eliminate articles that clearly failed to meet the search criteria. Any disagreement between the authors was resolved via discussion.

Full-text copies of all remaining articles were obtained and further examined independently by each reviewer to determine whether or not they were eligible for this study based on specific inclusion and exclusion criteria.

Published studies were selected for inclusion based on the following criteria:

1. Human studies
2. Randomized controlled trials, prospective clinical cohort, or crossover studies
3. Use of photodynamic therapy as adjunctive treatment for the disinfection of root canal systems
4. Inclusion of permanent teeth with fully formed apices undergoing endodontic treatment
5. Report of outcomes of reduction in bacterial load
6. English language

Studies were excluded if they were animal studies or *in vitro* investigations, did not quantify the antimicrobial effect of PDT, did not specify the pulp and periradicular status, or did not follow a consistent endodontic procedure for all participants.

The investigators then scrutinized the remaining list of articles to reach a consensus that the inclusion and exclusion criteria were followed and that key studies were not missed. In case of a disagreement that was not resolved with discussion, the opinion of a senior reviewer was sought to determine definitive inclusion or exclusion of the article. Inter-reviewer agreement was assessed using Cohen kappa statistics.

Quality assessment of randomized clinical trials and observational studies was performed using the CONSORT (CONsolidated Standards Of Reporting Trials) statement criteria (25) and the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) statement criteria (26), respectively. The risk of bias for each of the included studies was reported as low, moderate, or high (27).

### Data Extraction

Two reviewers independently mined data regarding the year of publication, location of data, source of funding, number of participants in each group, number of interventions, and outcomes for each study and entered them in an electronic sheet. Because of the limited follow-up time in the published studies, the effect of PDT on the reduction of the bacterial load during root canal disinfection was considered to be an acceptable surrogate outcome measure and was evaluated as the primary outcome variable.

## Results

A total of 57 titles and abstracts were identified after an electronic search in both electronic databases using the specific combination of terms and key words. No additional studies were identified as relevant after a search of the reference lists. After the first phase of selection, 53 articles were excluded based on the predefined exclusion criteria (inter-reviewer agreement: $\kappa = 0.938$). Reasons for exclusion were studies identified as irrelevant to the specific PICO question ($n = 16$), *in vitro* studies ($n = 29$), an animal study ($n = 1$), and review articles ($n = 7$).

Full-text articles were retrieved for the remaining 4 articles and underwent independent review by each of the reviewers. After scrutiny, 1 article was excluded because it was a duplicate report of findings from another study (16, 28) (inter-reviewer agreement: $\kappa = 1$). The remaining 3 studies (16, 19, 20) fulfilled the inclusion criteria and were included in this systematic review.

Figure 1 presents a flowchart of the systematic review process according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The basic characteristics of the included studies are presented in Table 1. One study was a crossover clinical study (16), and 2 were uncontrolled clinical studies (19, 20). All studies were conducted in private practice settings, and treatment was performed by a single practitioner in each study. In 1 study, tolonium chloride was added as a photosensitizer for 60 seconds and then activated using a diode laser (ie, wavelength: 633 ± 2 nm, power: 100 mW, time: 120 seconds). The laser emitter was inserted in the root canal within 4 mm from the working length before photoactivation (16). In the studies by Garcez et al (19, 20), the photosensitizing agent used was a polyethylenimine and chlorine (e6) conjugate (ie, 60 μmol added for 120 seconds) photoactivated with a diode laser (ie, wavelength:660 nm, power: 40 mV, time: 240 seconds). The laser fiber was placed in the apical portion of the root canal until resistance was felt and then moved from the apical to the coronal direction with manual spiral movements (19, 20). None of the included studies reported any adverse events associated with the use of PDT. The small number of studies and the heterogeneity noted in the PDT protocol and inclusion criteria among the included studies did not allow us to conduct a meta-analysis.

### Primary Outcomes

The primary outcome in each study was the effect of PDT on the microbial load (or number of microbial species) in the root canal system as measured using microbiological sampling methods and analyses (Table 2).

### Effect of PDT on Initial Root Canal Treatment

Bonsor et al (16) compared the antimicrobial efficacy of PDT to 2.5% NaOCl in the initial root canal treatment and concluded that