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Review Article

USING PHOTODYNAMIC THERAPY IN ROOT CANAL SYSTEM – A LITERATURE REVIEW

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ABSTRACT

Microorganisms do play in pulpal and periapical infection. Success of endodontic treatment aims at effective eradication of bacteria from the root canal space. This, in turn, prevents further microbial recolonization. Persistent microbial colonies in the root canal lead to failure of the endodontic treatment. With the advent of photodynamic therapy (PDT), a novel invasive approach is aimed at complete disinfection of root canal with elimination of bacteria. Therefore, this paper aims to highlight the efficiency of PDT in endodontics by reviewing the literature published in journals

Keywords: Bacteria, *Enterococcus faecalis*, Microorganism, Photodynamic therapy, Root canal.

INTRODUCTION

Various microorganisms play an important role in pulpal and periapical infection. The reason for this failure is due persistence of microorganism causing infection by formation of biofilm [1,2]. Primary endodontic infections are associated with Gram-negative anaerobic rods whereas secondary endodontic infections are associated with Gram-positive bacteria with no apparent facultative anaerobes [3].

Persistent microbial infections and anatomical alterations of the root canal in the apical region due to its complexity do not disinfect the canal completely. Moreover, in secondary infection, the most commonly isolated bacteria are *Enterococcus faecalis* [4]. The success of treatment in such case needs an additional treatment of microbial elimination and disinfection.

Aiming to increase the efficiency of disinfection, photodynamic therapy (PDT) also known as photo activated disinfection or photo chemotherapy was developed [5] PDT is a non-invasive approach developed in recent years. This paper highlights the efficiency of PDT in endodontics by reviewing the literature published in journals.

HISTORY

Over 100 years back, first report showed the association between dye and light producing antimicrobial effect [6]. In the year 1900, Raab and von Tappeiner [7] found that red acridine absorb ambient light and produce toxic effect on protozoa.

Gordon Gould in the year 1957 introduced the term light amplification by stimulated emission of radiation (LASER) [8]. Helium neon laser was first invented by Ali Javan in 1960 [8]. Robot Hall invented diode laser in the year 1962 [8]. In the same year, EndreMester introduced low level laser therapy [9]. At present, it is known that various microorganisms can be eliminated by activating a nontoxic photosensitizing using a resonant light source [10].

PDT

Light-induced inactivation of microorganism is defined as PDT [11]. The use of photosensitizer (PS), that is, photo activated dye, at a specific wavelength gets activated by light in the presence of oxygen [12,13].

PS

The properties of PS are low cytotoxicity, photosensitivity, simplicity, reducibility, high stability, high affinity, and bacterial penetrability [14]. PS is a light sensitive non-toxic dye. PS when irradiated by light of suitable of wavelength, result in destruction of microorganisms 0.5–1.5 cm depth of penetration will be achieved when the PS absorbs light of a wavelength between the range of 630 and 700 nm. Cyanines are capable of absorbing light when irradiated at a wavelength of 600–805 nm. Phytotherapic agents absorb light at 550–700 nm. At a range of 620–650 nm hematoporphyrin derivatives absorb light. AP henothiazine derivative such as Toluidine blue and Methylene blue which absorbs light at a wavelength of 620–700 nm [15]. In endodontics, the most commonly used PS is phenothiazine derivatives.

PS can be divided into three types based on antimicrobial purpose. The PS that strongly binds the microorganism, example chlorine. PS which weakly binds are Phenothiazine derivative and PS which does not bind is Rose Bengal [16]. It was stated that there was an increase in antibacterial efficiency when concentration of methylene blue and light energy fluence is increased [17].

Toluidine blue even in the absence of light interacts with lipopolysaccharide of Gram-negative bacteria [18]. Previous report stated that when exposed to a maximum absorption, destruction of microorganisms take place at a wavelength of 630 nm [19].

LIGHT SOURCE

The light of suitable wavelength should be used for effective treatment; therefore, LASER light should be preferred [4]. Every light source has a specific wavelength such as Helium-Neon lasers (633 nm), Gallium-Aluminum-Arsenide diode lasers (630–690, 830, or 906 nm), and argon lasers (488–514 nm) [4]. For effective microbial reduction, the most commonly used light sources are Helium Neon and diode laser [20].

At present, non-laser source of light such as light emitting diode is being used because it is less expensive, light weight, and flexible [4].

MECHANISM OF ACTION

On irradiation of light at a particular wavelength, there occurs transition of PS to exited singlet state from ground state. The PS then either return back to ground state with fluorescence emission or exist in high energy triplet state. At this stage, two types of reactions take place.

In first type of reaction, direct transfer of electron or hydrogen from PS produce electron or hydrogen removal from the substrate molecule to form free radical. This free radical reacts with oxygen resulting in highly reactive oxygen species leading to destruction of microorganism [21].

In second type of reaction, exited state oxygen gets released namely singlet oxygen causing rapid destruction of selected tissues. It is stated that type 2 reactions are the most accepted pathway as the majority of the microbial cell undergo destruction [21].

COMPARATIVE STUDIES

Ng *et al.* [22] selected extracted teeth with pulp necrosis. The study was done comparing 6% sodium hypochlorite and PDT usage. The concentration of methylene blue used was 50 µg/mL and diode LASER at a wavelength of 665 nm connected to an optical fiber. The result showed PDT was able to eliminate 86.5% of microorganisms in the canal and only 49% microbial elimination when PDT was not used.

The previous reported that 2.5% sodium hypochlorite and PDT using 15 µg/mL Toluidine blue and diode LASER at a wavelength of 625 nm eliminate *E. faecalis* in single-rooted canals of freshly extracted teeth [23].

It was reported that of 0.01% of methylene blue, when activated at a wavelength of 660 nm produce large amount of singlet oxygen which resulted in reduction of microorganism [25]. Pagonis *et al*. [25] reported eradication of *E. faecalis* in experimentally infected root canals when irradiated using poly lactic-co-glycolic acid nanoparticles loaded with methylene blue (50 µg/mL).

In an extracted tooth survival rate of *E. faecalis* within the root canal is 0.1% when PDT is used along with 6% sodium hypochlorite. PDT or sodium hypochlorite when used separately showed survival rate of microorganisms to be 2.9% and 0.66%, respectively [26]. Endodontic treatment showed better results with the use of optic fiber when compared to LASER light directed into the access cavity against *E. faecalis* [27].

On comparing the efficacy of PDT in planktonic suspensions and mono-species biofilm *Pseudomonas aeruginosa* and *E. faecalis*, it was reported that there was increase in antibacterial efficiency when formulation of PS was modified [28].

Use of oxidant and an oxygen carrier along with methylene blue resulted in increased potential of photo-oxidation and generation of singlet oxygen of PDT, leading to the disruption of the biofilm matrix of *E. faecalis* in root canals [29].

It was reported that there was a substantial decrease in microbial count in primary endodontic infections with Toluidine blue O -mediated PAD [30].

The previous study reported effective elimination of biofilm formed by *E. faecalis* in polystyrene plate when microbial efflux pump inhibitor was added along with methylene blue [31]. The studies reported that PDT alone showed greater reduction in bacteria than PDT with 3–6% sodium hypochlorite, or conventional chemomechanical preparation. It was seen that both sodium hypochlorite and chemomechanical preparation when used alone showed better results in bacterial reduction [32,33].

Samiei *et al*. [34] concluded that 2.5% NaOCl was significantly better than that of PDT technique. In addition, 2.5% NaOCl was significantly better than 2% chlorhexidine (CHX). Bolhari *et al.* [35] reported that use of adjunctive antimicrobial PDT in combination with 2.0% CHX was an effective approach for reduction *E. faecalis* biofilm within the root canal space.

Shrestha *et al*. [36] reported that lipopolysaccharide and other inflammatory markers can be inactivated by combining PDT with

Table 1: Various studies done using photodynamic therapy and the percentage of bacterial elimination in root canal

Reference	Year	Study type	Microorganism	Bacteria ↓
Seal *et al.*	2002	*Ex vivo*	*Staphylococcus intermedius*	5log10
Bonsor *et al.*	2006	*In vivo*	*Staphylococcus intermedius* naturally infected teeth	96.7%
Bonsor *et al.*	2006	*In vivo*	Polymicrobial naturally infected teeth	91%
Williams *et al.*	2006	*In vivo*	*Fusobacterium nucleatum, Peptostreptococcus micros, Prevotella intermedia, and Staphylococcus intermedius*	99%
Silva Garcez *et al.*	2006	*Ex vivo/In vivo*	*Enterococcus faecalis*	99.2%
Soukos *et al.*	2006	*Ex vivo/In vivo*	*Porphyromonas gingivalis, Prevotella intermedia, Fusobacterium nucleatum, Peptostreptococcus micros, Porphyromonas endodontalis, Enterococcus faecalis*	97%
George and Kishen	2007	*In vitro/ex vivo*	*Aggregatibacter actinomycetemcomitans Enterococcus faecalis*	100/97%
Garcez *et al.*	2007	*ex vivo*	*Pseudomonas aeruginosa, Proteus mirabilis*	98%
Foschi *et al.*	2007	*ex vivo*	*Enterococcus faecalis*	77.5%
Fimple *et al.*	2008	*ex vivo*	*Porphyromonas gingivalis, Prevotella intermedia*	> 80%
Garcez *et al.*	2008	*In vivo*	Polymicrobial naturally infected teeth	99.9%
Bergmans *et al.*	2008	*Ex vivo* 93.8/88.4	*Streptococcus anginosus, Enterococcus faecalis, Fusobacterium nucleatum*	93.8/88.4
George and Kishen	2008	*In vitro/Ex vivo*	*Enterococcus faecalis*	100%
Fonseca *et al.*	2008	*Ex vivo*	*Enterococcus faecalis*	99.9%
Lim *et al.*	2009	*Ex vivo*	*Enterococcus faecalis*	99.99%
Pagonis *et al*	2010	*In vitro/Ex vivo*	*Enterococcus faecalis*	84.8%
Souza *et al.*	2010	*Ex vivo*	*Enterococcus faecalis*	> 99.48%
Upadya and Kishen	2010	*In vitro*	*Enterococcus faecalis*	100/99%
Kishen *et al.*	2010	*In vitro*	*Enterococcus faecalis*	100%
Garcez *et al.*	2010	*In vitro*	Polymicrobial/naturally infected teeth	100%
Schlafer *et al.*	2010	*In vitro/ex vivo*	*Escherichia coli, Candida albicans, Enterococcus faecalis, Fusobacterium nucleatum*	99.75%
Rios *et al.*	2011	*ex vivo*	*Enterococcus faecalis*	99.9%
Nunes *et al.*	2011	*ex vivo*	*Enterococcus faecalis*	> 99.41%
Garcez *et al.*	2013	*ex vivo*	*Enterococcus faecalis*	99.99%
Cheng *et al.*	2012	*ex vivo*	*Enterococcus faecalis*	96.96%
Shrestha *et al.*	2012	*In vitro*	*Enterococcus faecalis*	100%
Shrestha and Kishen	2012	*In vitro/Ex vivo*	*Enterococcus faecalis*	27–98%
Bago *et al.*	2013	*Ex vivo*	*Enterococcus faecalis*	99.99 %

chitosan conjugated rose Bengal Nanoparticles. George and Kishen [37] reported that PDT cause damage of cell wall integrity, deoxyribonucleic acid, and bacterial membrane protein. During PDT, PS influences the degree of damage. The previous report has shown that diode laser along with Pyoktanin was effective in eradiation of *E. faecalis* without having any toxicity to human dermal fibroblasts [38].

CONCLUSION

Use of PDT has potential advantage such as lack of scarring, highly selective tissue necrosis, significant reduction in bacteria, and precise directing the laser light using fiber optics. The most important advantage is that even after repeated exposures resistant to treatment do not occur. Thus, PDT is an important auxiliary tool for an effective disinfection of root canal.

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