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REVIEW ARTICLE

Laser-based Disinfection of the Root Canal System: An Update

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ABSTRACT

Introduction: Microorganisms have been considered to have played a critical role in the initiation and development of pulpo-periapical diseases. Some evidences have shown that mechanical instrumentation may leave considerable portions of canal surfaces undebrided. Therefore, some supplemental methods, such as the use of chemical solutions and/or lasers, have been introduced to further disinfect the complicated canal anatomy and destroy as many microorganisms as possible. The purpose of this review was to address a brief review of characteristics of lasers and their effects to disinfect the root canal in endodontics.

Keywords: Disinfection, Laser characteristics, Photon-induced photoacoustic streaming, Root canal system, Sodium hypochlorite.

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INTRODUCTION

In 1916, Einstein's[1] proposal stated that photons have the ability of stimulating the emission of identical photons from atoms that have been excited. Ladenburg[2] in 1928 showed some indirect documents for the process of stimulated emission. In 1940, Fabrikant[3] proposed that stimulated emission in gas discharge may have the ability of amplifying the light under suitable conditions. However, the weak point of this study was no long-term follow-up. After the Second World War, Lamb and Retherford[4] showed that nuclear magnetic resonance may produce population inversions. Also, the stimulated emission of radio waves was shown by Purcell and Pound.[5]

The first laser was produced by Maiman[6] by excitation of a ruby rod with intense pulses of the light from a flash lamp. The first actual generating laser (633 nm) was built by using a combination of helium and neon.[7]

The potential application of the ruby laser in dentistry was studied for the first time by Stern and Sognaes[8] and also by Goldman et al.[9] After initial studies with ruby laser, clinicians began using some other lasers, such as carbon dioxide (CO_2; 10,600 nm), argon (Ar; 514 nm), neodymium:Yttrium/aluminum/garnet (Nd:YAG; 1,064 nm), and erbium (Er):YAG (2,940 nm) lasers.[10] For the first time in endodontics, Weichman and Johnson[11] *in vitro* used high-power infrared laser to seal the apical foramen. After that, some other studies using Nd:YAG laser begin to show the ability of the laser to seal the apical foramen area.

LASER CHARACTERISTICS

Light amplification by stimulated emission of radiation, which has been abbreviated to LASER, is a single-photon wavelength. According to the statement of Einstein,[1] as excited atom can be stimulated to emit a photon before spontaneous occurrence of process, the lasing process can occur.[12] The release of subsequent photon may be stimulated by spontaneous emission of a photon by one atom. Laser is a monochromatic, collimated (with very low divergence), and coherent light. Lasers have the ability to concentrate the energy of the light and produce strong effect, targeting tissues at energy level lower than the natural light. Wavelength of the emitted photon has been stated to be dependent on energy of the electron when photon is released. When the states of electrons of two identical atoms are identical, wavelengths of released photons are identical, too.[13] Wavelengths emitted at the ultraviolet part of electromagnetic spectrum seem to be promising in endodontics. It has been proposed that the best laser to slow selective removal of necrotic debris from the canal and to leave smooth, crack-free melted dentin is the ArF excimer laser. XeCl excimer laser has the ability to melt dentin and close the dentinal tubules, too.[10,11,13]

Laser photons can interact with tissues in four ways: They are transmitted through the tissues, reflected from these tissues, scattered within tissues, or absorbed by such tissues. The tissue-absorption of the laser is basically due to the presence of proteins, free water, and also pigments. Absorption by molecules of the water plays an important role in thermal interactions, too. The absorption coefficient for water is 860 for CO_2 laser (10,600 nm), 0.61 for Nd:YAG laser (106 nm), 0.02 for diode laser (800 nm), 0.0002 for argon (514 nm), and 12,000 for Er:YAG laser (2,940 nm).[14]

ROLE OF MICROORGANISMS IN ENDODONTIC INFECTIONS

The role of microorganisms in initiation and development of pulpoperiapical diseases has been established in various animal and human studies,[15-17] but removing the microorganisms from the infected canal seems to be challenging. Numerous ways have been proposed to decrease microorganisms in the canal, including different instrumentation techniques, irrigating solutions, and various intracanal medicaments. A bacteria-free root canal cannot be achieved by the mechanical instrumentation alone[18] because the canal anatomy is complicated and not predictable.[19] It has been indicated that mechanical preparation of the anal leaves some areas of the canal undebrided,[20-24] so some additional techniques, such as usage of chemical solutions, may be required in order to disinfect the canal and destroy as many microorganisms as possible.

LASERS FOR THE ROOT CANAL DISINFECTION

A study revealed that Nd:YAG laser irradiation can considerably reduce intracanal bacteria, while irrigation with NaOCl effectively disinfected the root canals.[25] Gutknecht et al[26] showed that the bactericidal effect of the holmium-doped (Ho):YAG laser on the canals *in vitro* is very efficient. It has been also shown that laser irradiation may result in a significant decrease of bacteria for all dentin thicknesses.[27] Klinke et al[27] concluded that although after penetration of a 1,000-μm dentin, the intensity of the laser irradiation decreased and bactericidal mode of action was still effective. Using an animal model, Le Goff et al[28] showed that the NaOCl treatment was superior to the CO_2 laser treatment against *Actinomyces odontolyticus*.

Moritz et al[29] studied disinfecting potential of Nd:YAG laser through dentin and found that the Gram-negative bacteria showed immediate injury, but the Gram-positive bacteria needed repeated irradiation to achieve this aim. Perin et al[30] showed that Er:YAG laser and 1% NaOCl both were effective to the working length against all microorganisms studied, however, that 70% of the samples irradiated 3 mm short of the root apex remained infected.

Schoop et al[31] showed that the disinfecting effect of the erbium, chromium-doped yttrium, scandium, gallium and garnet (Er,Cr:YSGG) laser in dentin is dependent on the output power. Gordon et al[32] studied the ability of this laser to disinfect dentin and concluded that bacterial recovery decreased when laser duration or power increased. Application of 2 minutes laser resulted in better disinfection than with NaOCl usage. Bergmans et al[33] showed that Nd:YAG laser was not a suitable alternative, but a possible supplement to routine protocols of the root canal disinfection.

Berkiten et al[34] studied the effects of Nd:YAG laser on dentinal tubules inoculated with *Prevotella intermedia* and *Streptococcus sanguis*. Examination using the light microscope showed that the 1.8 W laser sterilized in 86% of the *S. sanguis* sections, and 2.4 W laser sterilized in 98% of these ones. In *Prevotella intermedia* group, both lasers sterilized all the samples.

Wang et al[35] showed that the Er,Cr:YSGG irradiation and Nd:YAG laser resulted in bacterial reduction of 77 and 97% after irradiation at 1 W respectively. Also, a reduction of 96 and 98% after treatment with Er,Cr:YSGG laser and Nd:YAG laser application at 1.5 W respectively.

Schoop et al[36] showed that Er,Cr:YSGG laser is a suitable device for intracanal bacteria elimination and also for homogeneous smear layer removal.

PHOTON-INDUCED PHOTOACOUSTIC STREAMING

Photon-induced photoacoustic streaming (PIPS) basis is on radial firing stripped tip with laser impulses of subablative energies of 20 mJ at 15 Hz. These impulses may induce water molecule's interaction which may create successive shock waves inducing formation of intracanal fluid streaming, with no temperature rising. In fact, PIPS is considered as a form of laser-activated irrigating works without thermal effects by activating irrigation solutions. The mechanism is considered as inducing a strong photo-acoustic shock wave that can stream irrigation solutions three-dimensionally throughout the canal.[37,38]

Unlike some other conventional applications of the laser, placing the unique-tapered tip inside the canal itself is not mandatory but rather in chamber only. This has been indicated to effectively remove tissues and disinfect the tubules.[39,40]

Peters et al[41] showed that PIPS cannot completely remove bacteria from the infected tubules in the apical area but can induce less infection than passive irrigation with ultrasonic. Jaramillo et al[42] also found that this PIPS with 20 seconds Er:YAG irradiation, and 6% NaOCl may be very effective in inhibition of the growth of *Enterococcus faecalis*.

Ordinola-Zapata et al[43] evaluated PIPS effect by using 6% NaOCl for biofilm removal and concluded that infected dentin cleaning on the PIPS samples is better compared with the patient under investigation samples. Jaramillo et al[44] showed 100% disinfection on PIPS samples, with a total of 1 minute of irrigation (*in vitro*). Al Shahrani et al[40] also concluded that PIPS/6% NaOCl combination may be more effective than combination of PIPS and water.

In another *in vitro* study, Zhu et al[38] showed no significant difference in reduction of bacteria in NaOCl+et hylenediaminetetraacetic acid, NaOCl, and PIPS+NaOCl samples. Olivi et al[45] also concluded that PIPS can enhance the effect of irrigants commonly used during endodontic treatment. Although laser irradiation may be considered as a useful device for root canal disinfection, its potential risks is better to be assessed.[46-48]

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