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Application of High-Power Diode Laser and Photodynamic Therapy in Endodontic Treatment - Review of the Literature

SUMMARY

Lasers have found important role in clinical application, science and scientific research. *The aim of this review is to focus on using soft tissue laser in endodontic treatments.*

The main goal of endodontic treatment is elimination of pathogenic microorganisms from root canal system. Laser light has the ability to reach parts of the tissue and areas where classical techniques *and* instruments *cannot.* New approaches to disinfecting root canals have been proposed recently, which include the use of high-*power diode* lasers*,* as well as disinfection of the root canal by using photodynamic therapy. *A research is necessary to define a precise protocol for high-power laser and photodynamic therapy in treatment of the root canal system.*

Keywords: Diode Laser; Photodynamic Therapy; Endodontics

Dejan Marković, Dragana Rakašević, Dijana Trišić

Belgrade University, School of Dental Medicine
Belgrade, Serbia

LITERATURE REVIEW
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Introduction

Miaman[1] was first who introduced lasers in dentistry in the 1960s, and since then it led to the application of lasers in everyday dental practice. Beside clinical, lasers have found important role in science and scientific research. Modern day lasers represent results of years of the research. The first laser designed specifically for dentistry was introduced in 1989[2]. The medical community began to incorporate lasers for soft-tissue procedures in the mid-to-late 1970s, and oral surgery added the technology in the early 1980s. On the account of efficiency, specificity, comfort, and cost over the conventional modalities, lasers are indicated for a wide variety of procedures in dental practice[3-5]. The aim of this review is to focus on using soft tissue diode laser for disinfection of root canals in endodontic treatments.

Mechanism of Laser

The working of laser light depends on typical properties of electromagnetic radiation. While in nature most of the light is white, laser light is monochromatic, coherent and focused. Monochromatic means that it emits at a specific wavelength or frequency containing 1 or narrow spectral range. Laser light is generated as only 1 colour. Dental lasers may emit visible or invisible light. The waves of laser light are coherent. Each wave is identical in physical size and shape. Coherence means that all photons are in the same phase in time and space, and focus denotes a virtual mutual parallelism of the photons in the beam. Result of orientation is a very small divergence at large distances, which allows the laser beam to be easily controlled and focused.

Working of the laser and its effect on biological tissue is determined by interaction of laser radiation parameters, such as: wavelength, physical characteristics of the illuminated tissue, energy radiation, continuous or pulsed mode, diameter of the laser beam, and the exposure time. Laser beam passing through the tissue can be reflected, absorbed, transmitted and scattered. Proportion of reflection, absorption, transmission and scattering depends on the wavelength of the rays and the absorption capacity of the tissue[6-10].

Illumination by different wavelengths of the laser beam produces different absorption coefficients and depends on the tissue the laser beam acts. The target components of the tissue on which the laser beam acts are referred to as chromophores, such as water, protein, melanin, haemoglobin, hydroxyapatite, and other minerals. Knowledge of the composition of the target tissue is necessary in selecting the correct wave length of the laser. In this way we will achieve the desired absorption which is optimal for biological effects of lasers on tissue. The laser parameters - energy, beam diameter, and duration of exposure - must be carefully monitored to produce a successful treatment result.

There are 4 reaction mechanisms associated with the use of lasers in medicine, which depend on the therapeutic aim of laser treatment: photomechanical effect (photo-acoustic) i.e. for laser lithotripsy, removal of tattoos and certain pigmented lesions, photochemical effect i.e. photodynamic therapy (PDT), chemical reaction stimulation, photothermal effect i.e. laser resurfacing, treatment of vascular lesions, laser hair removal, and photobiostimulative effect i.e. low level laser therapy (LLLT), laser acupuncture, collagen remodelling for aged skin, anti-inflammatory treatments, accelerated wound healing[11-26].

It is important to note that the commercially available dental instruments all have emission wavelengths ranging from 488 nm to 10,600 nm and are all nonionizing radiation. This is to be distinguished from ionizing radiation, which is mutagenic to cellular DNA components[27].

Types of Lasers

In dental scientific and professional literature many experimental and clinical studies are described, as well as case reports that use different types of lasers of different wavelengths, such as: Carbon dioxide (CO_2) lasers, Nd:YAG lasers (1064nm), Er:YAG (2.94µm) and Er:YSGG lasers, Argon (488, 514nm) and krypton (513nm), and diode laser.

Due to extremely wide range of applications, diode lasers are now the most widely used types of laser devices in dentistry. Results of scientific and clinical studies indicate increasing application of diode lasers as an adjunct therapeutic agent. Diode lasers, depending on the wavelength and power irradiation can be used for incision, haemostasis and coagulation. Depending on the chosen parameters, lasers can have a significant antibacterial effect of direct ablation, thermal denaturation or destruction of bacterial cells. Thermolysis by laser energy achieved significant decrease of pathogenic flora[16].

Diode laser can be applied in many branches of dentistry: periodontics, oral medicine, oral surgery, maxillofacial surgery, restorative dentistry, endodontics, prosthetics, and paediatric dentistry.

Lasers in Endodontics

The development of new delivery systems, such as thin and flexible fibres, as well as new endodontic tips, allowed this technology to be applied in various endodontic procedures. The application of lasers in endodontics can be for: pulp diagnosis (laser doppler flowmetry), pulp capping and pulpotomy, cleaning and disinfecting the root canal system, sedative and anti-inflammatory treatment, endodontic re-treatment, apical surgery.

Disinfection of the Root Canal System

The main goal of endodontic treatment is to complete disinfection and elimination of the pathogenic microorganisms from the root canal system. It has been known that microbial infection plays an important role in the development of necrosis in the dental pulp and formation of periapical lesions[19]. It is well established that eradication of bacteria from root canals is difficult, and current endodontic techniques are unable to consistently disinfect the canal systems[20]. Endodontic therapy attempts to eliminate bacteria within the root canal system by utilizing protocols that combine mechanical instrumentation and chemical irrigation of disinfectant agents, such as sodium hypochlorite or hydrogen peroxide, the application of an inter appointment dressing containing an antimicrobial agent, and sealing of the root canal[21]. New approaches to disinfecting root canals have been proposed recently that include the use of high-power lasers[16,22], as well as disinfection of the root canal by using photodynamic therapy[16,23-25].

Disadvantages of conventional root canal treatments include their skill-dependent nature, long treatment time, possible weakening of teeth due to widening of the root canal, and use of medicaments such as sodium hypochlorite[25]. A disadvantage with irrigants might also be their inability to penetrate the deeper parts of dentinal tubules where microorganisms may reside[26].

Field of antibacterial chemotherapy is a constant challenge. The current problem of bacterial drug resistance perhaps best illustrates the continuing requirement both for new agents and new approaches to eliminate infection from root canal system.

Ng et al.[27] suggested that it would be superior to develop adjunctive antibacterial therapeutic strategies to chemo-mechanical methods to target residual microorganisms and thus enhance the healing rates of teeth with infected root canals.

The bactericidal effects when lasers are used as adjunctive therapy for root canal disinfection depend on the type of laser used. There is still lack of evidence for understanding the exact way of killing microorganism using the laser. The high-power diode laser has been tested in several areas of dentistry, with promising results for the disinfection of root canals[22,34-39]. It has been shown that laser light has the ability to reach parts of the tissue and areas where classical techniques and instruments cannot[16,22,29,31].

Nd:YAG lasers are thought to eradicate microorganism mainly by thermal effects, whereas the suggested bactericidal mechanism of action for Er:YAG lasers is linked to the strong water absorption of the laser output. Lasing parameters such as pulse length, fluency and irradiance are also suggested to be involved in the anti-bacterial effect[28].

High-power lasers function by dose-dependent heat generation, in addition to killing bacteria. Antibacterial effect is achieved by increasing temperature in root canals. When the transmitted laser light leads to the appearance of the thermal effects care must be taken not to damage the surrounding periapical tissues, anatomical structures (the mental foramen, mandibular canal). Earlier studies demonstrated that this form of therapy has no advantage over the classical application of sodium hypochlorite[16,32]. High-power laser have the potential to cause collateral damage, such as char dentine, root ankylosis, cementum melting, and root resorption and peri-radicular necrosis if incorrect laser parameters were used[33]. There is a need for new studies about using high-power laser in combination with sodium hypochlorite.

Lasers are also used in techniques that employ photo-activated substances or photosensitizers; however, the mode of action is completely different from the ones described above. This technique is photodynamic therapy (PDT) which was first developed as a cancer therapy. Today, PDT, or photo-chemotherapy is a non-invasive therapeutic modality for treatment of various infections by bacteria, fungi and viruses[40,41]. Mechanism of PDT involves 3 elements: a photosensitizer, a light and tissue oxygen. Antimicrobial photodynamic therapy (aPDT) could be used as an adjunctive therapy in the treatment of periodontitis[41,42], periimplantitis[41,43] , endodontics and caries[44,46,47] therapy.

PDT is defined as an oxygen-dependent reaction that occurs upon light-mediated activation of photo-sensitising compound leading to the generation of cytotoxic reactive oxygen species, predominantly singlet oxygen[40]. Photoactive substance (photosensitizer) binds to the target cell, and appropriate wave length activates this matter, which causes excitation of photoactive materials in the presence of oxygen. This process leads to the formation of free radicals (with the largest quantity of free oxygen) that lead to cytotoxicity and death of the target cell[40,41]. Previous studies have shown that Gram-negative bacteria are resistant to the photoactive material, in contrast to Gram-positive bacteria[45]. aPDT is without harmful effects on the surrounding hard and soft tissues[40,41,46,47].

There are many studies where aPDT is compared with another type of therapy, such as irrigation with different concentration of sodium hypochlorite[16,45,47], ozone therapy[32] or some another type of laser[16]. It has been shown that aPDT significantly reduces bacteria in root canals, which creates better results than conventional protocols and has much higher efficiency than high power lasers. Most research was done *ex vivo*; therefore more *in vivo* experiments are needed.

Conclusion

A precise protocol for aPDT or high-power diode laser therapy does not exist. It has not been determined how many sessions or repetitions of therapy are needed to create completely sterile conditions. A research is necessary to define a precise protocol for a PDT and high-power laser in therapy of the root canal. Looking to the future, it is expected that specific laser technologies will become essential components of contemporary dental practice over the next decade.

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Correspondence and request for offprints to:

Prof. Dejan Marković
University of Belgrade
School of Dental Medicine
Clinic of Paediatric Dentistry
Belgrade, Serbia
E-mail: dejan.markovic@stomf.bg.ac.rs