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Antimicrobial Activity of Laser Systems in Endodontics

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Abstract: ***Endodontic success is dependent on disinfection and debridement of the canal system. It has been well documented that bacteria and their products contribute greatly to the occurrence and development of pulpal and periapical diseases. Additional disinfection measures are necessary in order to eliminate and neutralize the microorganisms and their toxins. Laser has been examined as adjunct to current disinfection method and is an effective tool for killing microorganisms. Once our knowledge of optimal laser parameters for each treatment is complete, lasers can be developed that will provide dentists with the ability to care for patients with improved techniques.***

Keywords: Disinfection, Endodontics, Laser, Root Canal, Photodynamic therapy, Laser - enhanced irrigation

1. Introduction

According to National Academy of Sciences, laser development is one of the greatest achievements after one century of innovations in engineering. A laser is a device which transforms lights of various frequencies into a chromatic radiation in the visible, infrared and ultraviolet regions with all the waves in phase capable of mobilizing immense heat and power when focused at close range. Laser light has specific properties, useful especially in science and technology: monochromaticity, coherence and directionality. Depending on the optical properties of the tissue, the energy of the laser light can have 4 different interactions with the target: reflection, absorption, transmission and scattering.

The credit for development of the theory of spontaneous and simulated emission of radiation is given to Albert Einstein. The first laser (Light amplification by stimulated emission of radiation) constructed by Maiman was a pulsed Ruby laser, which emitted light of 0.694µm wavelength. The first laser in endodontics was reported by Weichman and Johnson who unsuccessfully attempted to seal the apical foramen in vitro by means of a high powered infrared laser.

The canal system within teeth is a complex array of accessory and lateral canals, fins, and other anatomical areas that are inaccessible with endodontic files. Endodontic success is dependent on disinfection and debridement of the canal system. Obturation, or sealing of the canal system, is dependent on how well the canal anatomy is cleaned of pulpal tissue and residual bacteria. Irrigation has been long accepted as a key part of treatment to achieve those goals. Complete clearing of residual bacteria, especially in the apical portion of the canal system, has been difficult to achieve with traditional instrumentation and irrigation methods, even when using sodium hypochlorite (NaOCl) irrigation solutions.

It has been well documented that bacteria and their products contribute greatly to the occurrence and development of pulpal and periapical diseases. The fundamental aim of endodontic therapy is the elimination of these etiologic agents from root canals and the disinfection of root canals and its three - dimensional tubularnet work with consequent repair of the periapical region. However, the overall reported success rate of endodontic therapy is about 85–90%, one of the main reasons of root canal therapy failure is the presence of persistent microorganisms such as Enterococcus faecalis (E. faecalis). Presently, sodium hypochlorite (NaClO) is the most commonly used canal irrigant due to its abilities such as tissue dissolution and effective disinfection [10]. It acts by direct contact with the bacteria targeted. Although it could penetrate to a depth of approximately 130 mm into dentinal tubules, microorganisms in the deeper layers of dentin still cannot be affected effectively. It is reported that persistent infection may occur at a depth approximately 300 mm into dentinal tubules even close to the cementum–dentin junction (up to 1, 000 mm). Besides, it is impossible for NaClO to completely eliminate bacteria located in areas such as accessory canals, anastomoses, and fins by itself.

Laser radiation was introduced into endodontic treatment for its bactericidal effect [1]. The bactericidal effect of various laser systems performed in different infected root canal models by themselves or accompanied with root canal irrigants have been investigated, and most studies showed favorable results with regard to bacterial reduction [9]. Studies have demonstrated that addition of laser activated irrigation greatly enhances not only the efficiency of the recommended irrigation solutions (NaOCL and EDTA), but also improves disinfection of the canal system. In recent years, various laser systems, namely Nd: YAG, diode laser, Er: YAG, and Er, Cr: YSGG laser, have been introduced into the field of laser - assisted endodontic therapy [14, 16].

2. Root Canal Desinfection

Traditionally, disinfection of root canal system is accomplished cleaning. Calcium hydroxide, aids NaOCI in dissolving organic debris, neutralises endotoxins, and further reduces the bacterial count; it is widely accepted as an intracanal dressing. However despite meticulous chemo - mechanical cleaning, the entire root canal system cannot be rendered bacteria - free. Most of microbes remaining in complex canal system are inaccessible to conventional instrumentation. Thus, persistant microorganisms have been shown to be a cause of treatment failure. Additional disinfection measures are necessary in order to eliminate and neutralize these microorganisms and their toxins. Laser has been examined as adjunct to current disinfection method. The laser is an effective tool for killing microorganisms because of the laser energy and wavelength characteristics. The respective wavelength, specific bactericidal capabilities, and potential usefulness in root canal disinfection of these laser systems have been well documented. Their relative microbicidal effect on the surface of root dentin slices of different thicknesses have also been investigated.

The laser wavelength described for cleaning of root dentine are CO_2, 9600 to 10, 600 nm; Er: YAG, 2949 nm; Er: Cr: YSGG, 2790 nm; Nd YAG, 1069 mm; Diode, 635 to 980nm and KTP laser, 532 nm. Lasers can be delivered into root canals using a hollow tube or thin fibre optics of 200µ. All lasers have a bactericidal effect at high power that is dependent on the irradiation parameters and expose time [2]. The root canal is irradiated after or at the same time with the irrigation procedure (distilled water, EDTAC, chlorhexidine, sodium hypochlorite).

It is unclear the real mechanism that stands for the laser decontamination of root canals [3]. The first mechanism proposed for explaining the bactericidal effect of laser irradiation was that the laser light is absorbed by bacteria and thus is responsible for direct destruction of the bacterial cell. It was considered that this phenomenon was due to the presence of black pigments in some bacteria (protoporphyrin IX), which can absorb a limited portion of wavelengths, especially those in the near infrared portion of the spectrum. Deterioration is produced at the membrane of the cell and induces osmotic alteration which translates into cell death. The second mechanism proposed suggested that laser light is absorbed strongly in dentinal substrate on which bacteria adhere, the resulting heat causes a local rise of temperature, that leads to the death of the microorganisms attached. However, some studies reported the existence of insignificant relationship between the temperature rise and the bactericidal effect. In this case, the bactericidal effect was linked to an unidentified photo damage effect, which contradicts with most studies that reported a bactericidal effect according to the power applied and the thermal effect of lasers.

The ability of different laser systems to disinfect root canals is principally a result of the heating effect. The most well designed clinical studies clearly demonstrates advantages of lasers over conventional methods [17]. Numerous studies have documented that the laser beam has the ability to remove debris and smear layer. Diode lasers have accomplished a bacterial reduction of E. coli of 76.06% (810 nm) and 68.15 % (940 nm). The laser light is thought to be able to reach areas that are inaccessible to the traditional techniques. The use of lasers allow the reduction of chemical irrigants, intracanal medicamentation and systemic antibiotics. This treatment protocol allowed a quicker healing of periapical lesions.

Matsumo et al. emphasized the possible limitations of the use of lasers in the root canal system. They suggested that " removal of smear layer and debris by laser is possible, however it is difficult to clean all root canal walls, because the laser beam is emitted straight ahead, making it almost impossible to irradiate the lateral canal walls. " So, microbes located in complex non geometric root canal system and also those in dentinal tubules are inaccessible. The authors strongly recommended improving the endodontic tip to enable irradiate all areas of root canal walls. The development of oblique light transmission systems, side firing tips and rotation, effectively reflect the microbicidal effect of the laser and significantly improved the results of laser - assisted endodontic treatment. Despite of elaboration of laser systems the application to extremely curved and narrow infected root canals appears difficult.

3. Laser Enhanced Irrigation

Some laser devices produce cavitation effects in root canals in a manner similar to that of the ultrasonic irrigation. At present, the effect is weaker than that of ultrasonic irrigation. This laser technique is likely to be improved in the future. Straight and slightly curved root canals as well as wide root canals are indications for this treatment. The pulsed Nd: YAG laser, Er: YAG laser, and Er, Cr: YSGG laser are recommended. A power of 2 to 5 W usually is used for approximately 2 minutes.

Application of the diode laser with endodontic irrigation is a good adjunct to conventional endodontic treatment when used in combination with NaOCl and other irrigants. Disinfection strategies using diode laser - activated irrigation yield promising results and have been reported to eliminate *Enterococcus faecalis* within the canal system [5]. *E faecalis* is a common microflora in saliva that has been associated with endodontic failure. The diode laser has two effects when activated in the irrigation solution within the canal system. The energy from the diode heats the irrigation solution, thereby improving the efficiency of the irrigant to exert its actions on the pulpal tissue and bacteria (NaOCl) or chelate the dentin (EDTA) within the root system. Diode lasers induced only modest temperature changes on the external root surface at the settings used, and they are safe for the periodontal tissues surrounding the tooth. Following instrumentation to a size 25 file (rotary or hand file), laser - enhanced irrigation is started, with the fiber of the diode extended to 2 - 3 mm from working length and activated. In multicanal teeth, the process is repeated in each of the canals [6].

The Er: YAG, Nd: YAG, and Er, Cr: YSGG lasers have also proven to improve endodontic clinical results by activating the irrigation solutions in the canal system. Antibacterial effects were reported to be the best with combination of irrigant and laser. The higher wavelength of the Er: YAG compared to the Nd: YAG or diode was more effective in smear layer removal, hence better at bacterial elimination within the canal system. These create hydrodynamic pressure following cavitation bubble expansion and collapse when the irrigation solution is activated in the chamber. A heat pulse is generated by laser radiation delivered via a sapphire tip into an absorbing liquid (irrigant), resulting in tensile stress and cavitation being induced in front of the tip at a distance. Bubble expansion and collapse cause the surrounding fluid to flow at a speed of up to 12 m/s traveling throughout the canal system. This causes rapid displacement of intracanal fluid to drive irrigants into the canal anatomy [13]. Access into the pulpal chamber may be performed with the Er: YAG, Nd: YAG, or Er, Cr: YSGG laser, which provides decontamination and removal of bacterial debris and pulpal tissue to yield a cleaner chamber. Laser - assisted canal irrigation requires canal preparation to an apical preparation ISO 25/30 with a taper of 0.04 or 0.06 [12]. NaOCl is utilized within the chamber and canals during instrumentation both as a pulpal tissue dissolvent and to lubricate the files within the canal.

4. Photodynamic Therapy

This technique is also known as photodynamic inactivation (PDI), photoactivated disinfection (PAD) or photodynamic antimicrobial chemotherapy (PACT) and involves applying a photoactiveor photosensitive dye (photosensitizer PS) which is capable of producing species of reactive oxygen when irradiated with light at the right wavelength for it to be absorbed by PS [4]. Photosensitive substances, such as methylene blue (MB), toluidine blue (TB), tolonium chloride (TC) and green indocyanine (IG), make the bacteria moresensible to laser light. In order to accomplish the PDT, PS must be capable to absorb efficiently light and then to transformit in one of the species of reactive oxygen: "singlet oxygen", anion superoxide and hydroxyl radical. Also, it has to present acertain degree of affinity for the microorganism membranes and to penetrate the microbial biofilm. Some bacteria produce their own PS and can be destroyed just by applying light. The PS produced is usually a porphyrin and can be excited efficiently with red or blue light. Unfortunately, the majority of organisms responsible for endodontic infections do not produce PS and thus the technique requires using external PS. External factors can interfere with the photoreaction, such as the interaction between phenothiazine dyes and blood or saliva from the oral cavity can reduce the efficiency in spite of correct illumination and PS concentration. Studies regarding the use of PDT in treating oral and dental infections are becoming popular. Particularities of this noninvasive method and bacterial resistance to antibiotics transformed PDT in an alternative to the treatment with chemical agents for eliminating bacteria in oral infections such as periodontitis and periimplantitis [7]. The results showed that endodontic therapy done with PDT is effective in bacterial reduction from root canal, both in ex vivo samples and in patients, although the success rate varies and comparint them is difficult (different PS, light parameters, ways of applying the light) [11].

Photodynamic therapy has been wildly applied in medicine for its bactericidal effect. It was reported that E. faecalis inside root canals could be reduced by 97.1% if treated with PDT alone for30 seconds or by 99.9% if treated with NaClO followed by PDT [15]. Thus, the potential bactericidal effect of laser irradiation can be used effectively for additional cleansing of the root canal system following biomechanical instrumentation [8]. The photodynamic effect appears to disrupt the biofilm by acting on both the bacterial cells and on the extracellular matrix extending tothe outer surface of the root. Although the light energy from the diode laser extends out to the periodontal ligament, it has been demonstrated that the method that is safe for periodontal tissues can also be used for endodontic purposes.

5. Conclusion

With the development of more advance mode of laser delivery the laser treatment will be more readily accepted. Lasers have become standard equipment in the dental practice and are a good tool for enhanced treatment in many areas. As outlined, tissue response is enhanced with an improvement in soft tissue healing, better hemorrhage control during treatment, and the ability to prepare teeth without the use of local anesthetic. All laser types have their pros and cons, and the choice of which laser to use depends on the treatment to be performed.

Once our knowledge of optimal laser parameters for each treatment is complete, lasers can be developed that will provide dentists with the ability to care for patients with improved techniques. The use of dental lasers for decontamination of the endodontic system is an alternative to conventional endodontic therapy. Side effects resulting from irradiation with laser light do not appear if the correct parameters are used.

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