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Review Article

Lasers in Root Canal Sterilization - A Review

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Abstract

Sterilization of root canal is an important step in the treatment to prevent the development of or to resolve any periapical pathology. Conventionally, chemo mechanical means have been used to clean the root canal systems. The most recent development in endodontic treatment is the use of lasers. The laser is an effective tool as it has the ability to kill the bacteria, remove debris and smear layer from the root canal walls following biomechanical instrumentation by the use of energy and wavelength characteristics. This article review goes on to explain, the effects of laser on tissue, bacteria, types of laser, delivery systems ,emission modes and about the use of lasers in root canal sterilization.

Key Words: Laser, Root Canal, Sterilization, Endodontics

Introduction:

Since bacteria are the most important cause of periapical infections, the main objective in endodontic therapy is the disinfection of the root canal and the three-dimensional network of dentinal tubules. From the infected pulp tissue, bacteria can penetrate into the deeper layers of root dentine and propagate a periapical inflammation with subsequent destruction of the adjacent connective tissue[1-3]. The local microenvironment favors the selection of relatively few bacterial species, which can survive and proliferate, being out of reach of the host's immune response[4-8]. The conventional chemo mechanical treatment for canal preparation and enlargement does not result in complete bacteria removal. The pathogenic microorganisms are able to penetrate the root dentine up to a depth of more than 1 mm, whereas disinfecting solutions reach a depth of only approximately 100 um. Very often the apical third of root canal remains insufficiently prepared, meaning that a smear layer made of dentin debris, pulp residue and bacteria may be found in it. Irrigation of smear layer from the dentinal tubules may be impossible, so the need for a new method to make endodontic treatment easier and more successful has become increasingly important[9].

The most recent development in endodontic treatment is the use of lasers. Since the development of the ruby laser by Maiman in 1960 and the application of the laser for endodontics by Weichman in 1971, a variety of papers on potential applications for lasers in endodontics have been published[10].

The first laser use in endodontics was reported by Weichman& Johnson (1971)[11-12] who attempted to seal the apical foramen invitro by means of a high power-infrared ($CO2$) laser. Subsequently, attempts were made to seal the apical foramen using the Nd:YAG laser[12]. Although more information regarding this laser's interaction with dentine was obtained, the use of the laser in endodontics was not feasible at that time. Since then, many papers on laser applications in dentistry have been published with growing interest in this topic in the last 5 years.

Lasers -penetration depth in Root Canal

Most currently use of irrigants and intra canal medicaments have limited anti-bacterial spectrum and a limited ability to diffuse into the dentinal tubules (100µm) therefore newer treatment strategies should be considered to eliminate microbes from the root canal system which penetrate upto 1,110µm. Laser light which penetrates up to > 1000µm into the dentin thus has scope for complete canal sterilization[13].

The laser is an effective tool for killing microorganisms because of the energy and wavelength characteristics. Infected root canals are an indication for this laser treatment, but its application in extremely curved and narrow infected root canals appears difficult[14].

Numerous studies have documented that CO2, Nd:YAG, Argon, Xe-Cl (308nm), Er,Cr:YSGG and Er:YAG laser irradiation has the ability to kill the bacteria, remove debris and smear layer from the root canal walls following biomechanical instrumentation. But lasers which can be delivered through extremely fine flexible fiber optic systems and which can penetrate dentin to a depth that can eliminate bacteria are applicable. This particularly includes lasers in the near infrared region[13].

Propagation of light in tubular network

The impact of the laser light depends on the interaction of the light quanta and the molecules and the molecular formations in the target material. Dentin has a complex tissue architecture composed of organic and inorganic material. The incident light is partly reflected and refracted but its main propagation is scattering, i.e. the splitting of the light by repeated directional diversion. Thus the original parallel beam of light loses its parallelism, the illuminating volume changes its form, and it becomes larger. The light emitted by the laser creates a “light fog” in the dentin, and does not have the characteristic of a concentrated beam anymore. This scattering is caused mainly by the tubules.

Laser light in near infra-red region is absorbed by dentin only to a small extent. For complete elimination of bacteria within the tubules, light should penetrate deep without interaction with the superficial dentin. Nd:YAG and diode laser wavelengths are not absorbed in hard dental tissue and are thus able to be effective in deep layers. The Er:YAG laser acquires its efficiency by photoablative effect. The antibacterial effect of Er:YAG is effective but restricted to a small area surrounding the root canal.

Reaction of bacteria to laser light

The laser light that attacks the bacteria may differ strongly from the light emitted by the fiber tip. This is because the light may have had an interaction with the dentin. Bactericidal effect of laser is attained by causing changes in bacterial cell wall. Because of the complex three layer membrane, gram negative bacteria are very sensitive to irradiation, and only very small densities of energy result in severe damage to the cell membrane of bacteria.

An indirect irradiation with 1W causes obvious changes to the cell membrane of bacteria. A number of large, vesicle formations of different sizes can be observed (so called membrane blebbing) which covers the bacteria totally or partly. The blebbing phenomenon is the result of the inner layer of the membrane splitting from the two outer layers. This change of the cell membrane impacts upon the barrier function and since the cell coat is also the site of a most diverse enzyme system; one can also assume that a slight restructuring of the membrane disturbs the cell’s metabolism substantially. In E. coli the changes of the murine – lipoproteins increase the sensitivity against EDTA and various other detergents, and changes also caused the loss, through the membrane, of periplasmatic enzymes like ribonuclease (this enzyme is involved in the reduplication and repair synthesis of the DNA).In comparison, the gram positive micro-organisms showed a higher resistance against irradiation. The reason seems to be the simple structure of the cell membrane. The cell wall of the gram positive E. faecalis shows an astonishingly high resistance against the laser irradiation. Low energies (1W) show almost no changes to these problematic bacteria.

With the application of multiple irradiations, visible damage of the bacteria can be detected, but there can still be a few unaltered cells. However, the quantitative bacterial death increases steadily, and the damage seems to depend on a cumulative effect. A cellular stress factor leads to sublethal, reversible changes, but when the cell is hit again by the irradiation it dies. This mechanism is called the “knock on” effect.

Different types of lasers and role in root canal sterilization

Numerous studies into the sterilization of root canals have been performed using CO2 and Nd:YAG lasers. Many other lasers such as the XeCl laser emitting at 308 nm, the Er:YAG laser emitted at 2.64 mm, a diode laser emitting at 810 nm, and the Nd:YAP laser emitting at 1.34 mm have also been used for this purpose.

Nd:YAG

The Nd:YAG laser is more popular that is because a thin fibre-optic delivery system for entering narrow root canals is available with this device and the ease with which the laser energy and laser fiber can be controlled[14].

Midda and Renton-Harper were the first to refer to the bactericidal effect of the Nd:YAG laser and recommended its use in endodontics. The first studies in this field were made in 1995 by Rooney et al. and Hardee et al.

Rooney et al. assessed the impacts of the Nd:YAG laser at different settings between 0.3W and 3W in vitro. For their evaluation, a 350µm fiber was used and excellent bactericidal effect was achieved. By adding black photo absorber, bacterial reduction could be reached at lower energies[15].

Hardee M.W. et al in their study on evaluation of the antibacterial effects of intra-canal Nd:YAG laser irradiation, concluded that there was no significant difference between groups exposed to pulsed Nd:YAG laser radiation or 0.5% NaOCl alone and in combination[16].

Thermal effects and antibacterial properties of an Nd: YAG laser was studied by Ramskold (1997) to establish clinically safe levels of energy to be delivered into the root canal and to determine the energy level needed to sterilize infected root canals[17]. The results indicated that lasing cycles of 3 J-s for 15 s followed by a 15-s recovery interval can be continued for prolonged periods without risk of thermal damage to surrounding tissues.

The antibacterial effects of the Nd: YAG laser on contaminated root canals and dentinal tubules were observed by Berkiten M. et al (2000)[16]. The samples were inoculated with Streptococcus sanguis (NCTC 7853) and Prevotellaintermedia (NCTC 93336), and the effects of Nd: YAG laser was tested on these teeth. The specimens were lased with 1.8 W and 2.4 W Nd: YAG laser for 30 s, and the presence of bacteria in tubules was observed under light microscopy. The 1.8 W lasers sterilized the tubules in 86.3% of sections inoculated with S. sanguis, whereas 2.4 W lasers sterilized in 98.5% of the sections. Both laser powers sterilized all samples inoculated with P. inter media. The scanning electron microscopic observations supported the light microscopic findings.

Diode Laser

It has unquestionable bactericidal effect, similar to the Nd:YAG laser. The sterilization effect of the diode laser resembles that of Nd:YAG laser[13].

The penetration depth of the diode laser, which is lower in the case of endodontics than that of the Nd:YAG laser, also lowers the risk of an unwanted temperature rise[18]. At the same time, however, this means less efficiency in the case of very deep infections. 980-nm diode laser can eliminate bacteria that has immigrated deep into the dentin[19] Since most diode lasers are chopped lasers, no pulse noise is to be heard and thus during application the valuable answer regarding the condition of the canal (damp or dry) is missing. Diode laser stimulates cell proliferation and shows inhibiting effect on inflammation propagating enzymes. In addition, Diode lasers have broad application spectrum. Diode lasers in addition to these qualities are having reasonable price, thus increasing their use in general practice.

Er:YAG and Er,Cr:YSGG Laser

For solitary root canal sterilization, the Er:YAG laser is not really suitable. It has a bactericidal effect through the removal of the smear layer in the root canal and is therefore comparable with the chemical rinsing solutions, described as "physical rinsing". However, the bactericidal effect in the depth of the dentin is not as good as achieved with the Nd:YAG or diode laser. It can only penetrate the areas closer to the canal lumen because of its wavelength and surface absorption by the dentin, and develop an effect on the bacteria[13].

A bactericidal effect in the depth of the dentin is hardly conceivable for physical reasons and could only be achieved through an unwanted temperature rise.

Excimer Laser

It is possible to demonstrate the bactericidal effects with irradiation with the 308nm excimer laser at an energy density below the threshold of ablation. A complete eradication of bacteria was achieved by applying 250 pulses. As the energy is increased upto 1.8J/cm[16] the number of pulses required to kill 90% of the bacteria decreases.

Because 308nm excimer laser ablates organic material much more easily than inorganic material the entrance of the root canals (orifice) can be easily found. With continuous saline rinsing and use of fiber with a core diameter of about 200µm, the lower third of the root canal is easy to reach. By varying the size of the optical fiber all of the root canals can be prepared with excimer lasers only. Studies have shown the most suitable energy density for root canal preparation to be 6-9J/cm^2 at a repetition rate of 20-30Hz. With these parameters smooth root canals were possible.

Risk of Laser during Endodontic Therapy

McKinley I.B. (1994) evaluated the potential for spreading bacterial contamination from the root canal to the patient and the dental team via the smoke formed by the laser. Extracted teeth were purposely inoculated with a definite strain of Escherichia coli. Argon laser was used in the canal. The smoke plume was captured and cultured. The cultures produced were positive for growth of the E. coli used. The authors concluded that the Laser smoke does present a hazard of bacterial dissemination and precautions must be taken to protect against spreading infections when using lasers in the root canal[19].

Conclusion:

Development of laser technology at this point of time is at a high state of refinement, having had several decades of researches. With the introduction of thinner, more flexible and durable laser fibers, its application in endodontics has tremendously increased. Newer laser systems are also focusing to improve the existing delivery systems, develop new fiber types, combine wavelengths into a single package, hence resulting into smaller and cost effective laser units.

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