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LASER IN ENDODONTICS

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ABSTRACT

LASER is light amplification by stimulated emission of radiation. Laser light is a manmade single-photon wavelength. The process occurs when an excited atom is stimulated to emit a photon. This is followed by subsequent release of another photon and so on. Stimulated emission generates, coherent (synchronous), monochromatic (single wave length), and collimated form of light LASER light when it reaches tissues gets reflected/ absorbed/scattered/transmitted to surrounding tissues. This is due to the presence of water, proteins, and pigments in biological tissues. This absorption coefficient of biological tissue strongly depends on the wavelength of LASER.

INTRODUCTION

LASER is light amplification by stimulated emission of radiation. Laser light is a man-made single-photon wavelength. The process occurs when an excited atom is stimulated to emit a photon. This is followed by subsequent release of another photon and so on. Stimulated emission generates, coherent (synchronous), monochromatic (single wave length), and collimated form of light.[1] LASER light concentrates light energy, i.e., photons and exert strong effect even at an energy level lesser than natural light. Photons thus emitted have a constant wavelength, and thus atoms with similar energy states will release identical photons - wavelength being constant. Hence, a LASER can be well described by its wavelength.[2] Wavelengths emitted at ultraviolet spectrum appear promising in endodontics. ArF LASER at 193 nm is well suited for removal of necrotic debris from root canal, leaving behind smooth, crack free and fissure free melted, dentine walls XeCl (308 nm) capable of melting dentin and closing of dentinal tubules.[1] LASER light when it reaches tissues gets reflected/absorbed/ scattered/transmitted to surrounding tissues. This is due to presence of water, proteins, and pigments in biological tissues. This absorption coefficient of biological tissue strongly depends on the wavelength of LASER.[3]

HISTORICAL PERSPECTIVE

In 1917, Einstein's paper on Quantum theory contained conceptual ideas for stimulated emission of radiant energy. Niels Bohr's Quantum mechanics concept that light has dual nature which gave the idea to fabricate optical resonators. In 1955, Gordon first demonstrated the stimulation of microwaves from the electromagnetic spectrum. In 1958, Schawlow and Towne have showed that emission of radiant energy in the form of photons in infrared (IR) and visible spectra. In 1960, Maiman constructed the first working LASER by exciting a ruby rod with intense pulses of light using a flash lamp. In 1961, Javan et al. produced the first continuous working LASER using Helium and Neon. Stern and Soagnes, Goldman et al. were pioneers to investigate potential uses of Ruby LASER in dentistry. Weichman and Johnson attempted to seal apical foramen in vitro by means of high powered IR CO_2 LASER.

Applications of LASER in Dentistry

1. Diagnosis of dental pulp vitality
2. Management of dentinal hypersensitivity
3. Pulp capping and pulpotomy (vital pulp therapy)
4. Modification of root canal walls
5. Sterilization of root canal system
6. Cleaning and shaping of root canal system
7. Obturation of root canal
8. Endodontic surgery
9. Tooth bleaching.

Diagnosis of Dental Pulp Vitality

LASER Doppler flowmetry is a non-invasive method of assessing and measuring the blood flow of pulp tissue. Advantages include the technique is more objective and reliable in assessing the health of pulp tissue. It has advantages of storing data, for measurements to be compared at later stages. Drawbacks include its technique sensitive, requires preparation of putty splint to hold probes and expensive.[4]

Lasers in Vital Pulp Therapy

Vital pulp therapy (pulpotomy) procedures using a LASER produce a bloodless field by vaporization and coagulation sealing smaller blood vessels and sterile wound. Melcer et al. used CO2 LASER on beagle dogs and monkeys to achieve hemostasis after pulp tissue exposure.[2] Moritz et al. used CO2 LASER for direct pulp capping compared with calcium hydroxide. Results showed, after 12 months, success rate of 89% with LASER and 68% with calcium hydroxide. Another study was conducted by Nair et al. using CO2 LASER in 5 teeth. After 7 days, none of 5 teeth showed any pathologic changes at pulp-dentin complex 3 months post-operative 2 teeth showed subtle, yet, distinct apposition of tertiary dentin.[3] One specimen showed mild inflammatory change with chronic inflammatory cells. This was attributed to antigens or micro-leakage rather than LASER therapy. Odabas et al. compared clinical, radiographic, and histopathologic effects of Nd:YAG LASER pulpotomy to formocresol pulpotomy for 12 months. Results showed that LASER group had a clinical success rate of 85.71%, and radiographic success rate of 71.42% formocresol group showed 90.47% success rate both clinically and radiographically.[5]

Lasers in Disinfection of Root Canal System

Elimination of microorganisms is commonly done to reduce the numbers of root canal micro-organisms, including the use of various instrumentation techniques, irrigation regimens, and intracanal medicaments. The bactericidal potential is developed through direct cell contact.[4] Regarding penetration of dentinal tubules, it has been demonstrated that NaOCl and Ca(OH)2 have a limited ability (about 130 µm) to penetrate and disinfect.[5] Chlorhexidine and IKI are a more effective in dentinal tubules than pure Ca(OH)2 in a water vehicle, but no complete disinfection has been established. Direct contact between target and fiber tip is not required, emission of laser energy could represent a way to disinfect areas deep within the dentine.[1] Moshonov et al. compared the efficacy of Nd: YAG laser irradiation with that of NaOCl in disinfecting the root canal system. Results showed that Nd:YAG laser irradiation significantly reduced the number of bacteria while NaOCl irrigation effectively disinfected the canals.[3] Perin et al. evaluated the antimicrobial effect of Er:YAG laser irradiation versus 1% sodium hypochlorite irrigation for root canal disinfection. Findings showed that the NaOCl solutions and the Er:YAG laser irradiation to working length were effective against all microorganisms.[1] However, 70% of the specimens irradiated 3 mm short of the apex remained infected. Le Goff et al. compared the bactericidal action of the CO2 LASER on animal teeth infected with Actinomyces odontolyticus, with that of NaOCl.[2] Results indicated an average 85% decrease in the colonyforming units in the laser-treated group, compared with the control group. However, the NaOCl treatment was statistically superior to the CO2 laser treatment.[3] Moritz et al. assessed the disinfecting potential of Nd:YAG laser irradiation through dentine on Gram-negative and Gram-positive bacteria with regard to their cell structure.[5] They found that whereas the Gram-negative test organism showed immediate structural injury, the Gram-positive test organism required repeated application of irradiation and concluded that the construction of the cell wall was crucial for their individual sensitivity to laser treatment. Gutkencht et al. determined the bactericidal effect of the Ho:YAG laser on root canals in vitro and found that it was very efficient.[2] Klinke et al. evaluated the bactericidal effects of Nd:YAG laser irradiation in different thicknesses of root canal dentine and found highly significant elimination of bacteria for all thicknesses. Gordon et al. investigated the ability of an Er,Cr:YSGG laser with radial emitting tips to disinfect Enterococcus faecalis-infected dentine.[6] They found that bacterial recovery decreased when laser irradiation duration or power increased. A greater degree of disinfection was achieved with a 120 s application of laser than with sodium hypochlorite treatment.[2] Similar conclusions were drawn by Schoop et al. Bergmans et al. assessed the bactericidal effect of Nd:YAG laser irradiation on some endodontic pathogens ex vivo. They concluded that the Nd:YAG laser irradiation was not an alternative but a possible supplement to existing protocols for canal disinfection as the properties of laser light may allow a bactericidal effect beyond 1 mm of dentine.[1]

Effect of Laser on Root Canal Dentin

Walls Endodontic instrumentation produces organic and mineral debris on the wall of the root canal. Although this smear layer may be beneficial in that it provides an obstruction of tubules and decreases dentine permeability, it also may harbor bacteria and bacterial products.[3] Pashley et al. evaluated the effect of a CO2 laser on the structure and permeability of smear layer covered human dentine in vitro. Three different energy levels were used (11, 113, and 566J/cm2). The lowest exposure to the laser energy increased dentine permeability. The intermediate energy level also increaseddentine permeability by crater formation, making the dentine thinner. The highest laser energy produced complete glazing of the crater surfaces and sealed the dentinal tubules beneath the crater.[5] Tewfik et al. evaluated a modified Nd:YAG laser called the KTP/532 laser to determine whether it would modify dentine permeability or alter the scanning electron microscopic appearance of canal dentine. The results showed that this laser did not change the permeability of the smear layer covered dentine, although scanning electron microscopy (SEM) examination revealed modifications to the surface of smear layer.[3] Takeda et al. evaluated the effects of three endodontic irrigants and two types of the laser on a smear layer created by hand instrumentation in vitro in the middle and apical thirds of root canals. Results showed that irrigation with 17% EDTA, 6% phosphoric acid, and 6% citric acid did not remove the entire smear layer from the root-canal system. In addition, these acidic solutions demineralized the intertubular dentine around tubular openings, which became enlarged.[4] The CO2 laser was useful in removing and melting the smear layer on the instrumented root-canal walls and the Er:YAG laser was the most effective in removing the smear layer from the root-canal wall.[7] Pecora et al. analyzed in vitro the effect of Er: YAG laser on dentine root canal wall permeability after endodontic instrumentation and irrigation with water or sodium hypochlorite and Er:YAG laser application. The instrumentation of the root canal using water as the irrigating solution followed by Er:YAG laser irradiation promoted the greatest increase in dentine permeability.[3] The use of an Er:YAG laser, 1% sodium hypochlorite + ErYAG, and 1% sodium hypochlorite used alone showed an intermediate capacity of increasing dentine permeability. The use of water as the irrigating solution without Er:YAG laser promoted the least dentine permeability. Kaitsas et al. evaluated the morphological and histological changes on the root canal walls after Nd:YAG laser application. The root canal walls irradiated with Nd:YAG laser showed a clear glazed surface, some open dentinal tubules and some surface craters with cracks.[2] Moshonov et al. compared the efficacy of root canal cleanliness with and without Nd:YAP laser application and assessed the laser effect on the dentine's mineral content. The cleanliness of the laser treated teeth was significantly greater than teeth treated with K-files alone.[4]

Lasers in Root Canal Shaping

Root canal shaping aims at removal of organic tissues and facilitates irrigation and canal obturation. The laser beams can be delivered through an optical fiber that allows for better accessibility to the root canals. The technique requires widening the root canal by conventional methods before the laser probes can be placed in the canal.[6] The fibers diameter, used inside the canal space, range from 200 to 400 um, equivalent to a No. 20-40 file. Levy found thatclean and regular root canal walls could be achieved using Nd:YAG laser irradiation from apical to coronal surface in a continuous, circling fashion.[2] Sousa-Neto et al. evaluated the adhesion of an epoxy-based sealer to human dentine with Er:YAG or Nd:YAG laser. Increase in frequency of the lasers, independent of power settings, increased adhesion of an epoxy-based root canal sealer. Varella and Pileggi evaluated the number of canals and isthmuses obturated after Cr, Er:YSGG laser treatment.[2] They found that Cr, Er:YSGG treatment resulted in a statistically significant greater number of canals/isthmuses obturated. de Moura-Netto et al. assessed the influence of Nd:YAG and diode laser irradiation on apical sealing when applied before root canal filling with two different resin-based cements (AH-Plus and EndoREZ). The SEM analysis as well as leakage results revealed better filling adaptation for the AH-Plus and Nd: YAG laser group.[7]

Limitations of Lasers In Root Canal Shaping

Optic fibers do not touch all canal walls meaning that areas with clean surfaces are interspersed with those covered by residual debris; this is compounded by severely curved canals.[5]

Lasers in Root Canal Obturation

Three-dimensional cleaning, disinfecting, and shaping of the root canal system is the major aim of modern root canal treatment along with sealing without leakage from the apical foramen to the crown. Maden et al. compared the apical leakage of lateral condensation, Nd:YAG laser-softened gutta-percha and System-B techniques and found no significant difference between the groups. "The lateral condensation group and the group treated with System-B showed less leakage than the group of laser-softened gutta-percha."[8] Anic and Matsumoto found that Argon and Partial CO2 lasers are more suitable for softening the gutta-percha fragments in the apical third of the root canal. Anjo et al. studied usefulness of a pulsed Nd:YAG laser in removing two types of endodontic obturation material from the root canal. Concluded that Nd: YAG laser irradiation was an effective tool for the removal of root canal obturation materials, and may offer advantages over the conventional method.[4]

Lasers in Treatment of Dentinal Hypersensitivity

Lasers used for treatment are divided into two groups:

1. Low output power lasers (He-Ne and gallium/aluminum/ arsenide [Ga/Al/As] lasers),
2. Middle output power lasers (Nd: YAG and CO2 lasers).

Kumar and Mehta evaluated clinically and under SEM the efficacy of Nd:YAG laser irradiation alone and in combination with 5% sodium fluoride varnish in the management of dentine hypersensitivity.[2] They found that the combination of Nd:YAG laser and 5% sodium fluoride varnish seemed to show animpressive efficacy, when compared to either treatment alone, in treating dentine hypersensitivity Aranha et al. evaluated the effects of Nd: YAG and Er:YAG lasers on reducing dentine permeability by sealing opened tubules.[3] Results showed that the Er:YAG laser at 60 mJ, 2 Hz, and the Nd:YAG laser at 1.5 W, 15 Hz are useful for decreasing dentine permeability. The effectiveness of lasers for treating DH varies from 5% to 100%, depending on the type of laser and the treatment parameters. Studies have reported that the Nd: YAG laser, the Er:YAG laser and Ga-Al-As low-level laser reduced Dentin Hypersensitivity.[1]

Lasers in Periradicular Surgery

Apicectomy is a surgical procedure in which the root apex is removed; the adjacent periapical tissues are removed and curetted at the same time. LASER used for the surgery provides a bloodless surgical field by vaporizing tissue and coagulating and sealing small blood vessels. If the cut surface is irradiated, the surface is sterilized and sealed.[3] Er:YAG laser can cut hard dental tissues without significant thermal or structural damage. Miserendino using the CO2 laser, in an apicectomy, for the treatment of a secondary apical abscess was able to seal the dentinal tubules in the apical portion of the root and to sterilize the affected area Gouw-Soares investigated the use of Er:YAG, Nd:YAG, and Ga-Al-As lasers in periapical surgery clinically.[5]

About 3 years follow-up showed radiographically significant decrease of the radiolucent periapical area and no clinical signs and symptoms Oliveira et al. and Arisu et al. evaluated the morphological changes and apical dye penetration at apical dentine surfaces. The groups irradiated with a laser showed to have lower infiltration indices.[1] LASERS in Tooth Bleaching Power bleaching or in-office bleaching produces the whitening results quickly, without the long-term commitment of wearing trays. Abbots used high-intensity light to raise the temperature of hydrogen peroxide, accelerating the chemical process of bleaching. The energy source can be derived from: 1. Blue-colored halogen curing lamps 2. IR CO2 lasers 3. Blue-colored plasma arc lamps 4. Cool blue argon laser 5. 980 nm Ga-Al-As laser. Luk et al. compared the whitening effects and tooth temperature changes induced by various combinations of peroxide bleaches and light sources. A placebo gel (control), a 35% hydrogen peroxide or a 10% carbamide peroxide bleach was placed on the tooth surface and was irradiated with no light (control), a halogen curing light, an IR light, an argon laser, or a CO2 laser.[4] Their findings demonstrated that color and temperature changes were significantly affected by an interaction of the bleach and light variables. The application of lights significantly improved the whitening efficacy of some bleaching materials but it caused significant temperature increases in the outer and inner tooth surfaces. The IR and CO2 laser lights caused the highest tooth temperature increases.[3] Eldeniz et al. measured intrapulpal temperature rise induced by two kinds of bleaching gels when the tooth was exposed to a variety of light curing units and a diode laser in vitro. Light activation of bleaching materials with diode laser caused higher temperature changes as compared to other curing units and the temperature rise detected was viewed as critical for pulpal health. Zhang et al. examined the whitening efficacy of a light-emitting diode (LED), a diode laser, and KTP laser irradiation in dental bleaching by analyzing the change in color achieved from the treatment, the temperature increase induced in the pulpal cavity, as well as enamel microhardness measurement after treatment.[3] The results showed that the KTP laser was effective at providing brighter teeth. According to the conditions used in this study, the LED and KTP laser induced a safer pulpal temperature increase when assisted with Hi-Lite bleaching gel.[8]

Side Effects of Lasers

During laser usage for intracanal applications, thermal injury to periodontal tissues is of concern. Eriksson and Albrektsson found that the threshold level for bone survival was 47°C for 1 min. Bahcall et al., for the 1st time, reported the effect of the Nd:YAG laser on periodontal tissues in dogs.[3] They found that the laser-treated teeth exhibited ankylosis, cemental lysis, and major bone remodeling. Kimura et al. found that laser systems operate in various modes, such as continuous wave, pulsed, chopped-wave, and Q-switched.[1] To minimize the rise in tissue temperature within the target and surrounding areas, use of the Q-switched nanosecond pulsed mode was beneficial. Cohen et al., Gutknecht et al., Nammour et al. suggested use of a LASER in a pulsed mode to avoid thermal increase and potential tissue damage.[7]

CONCLUSIONS

"In the presence of good research and corresponding systematic review, a complete knowledge of the optimal LASER parameters for each treatment modality is acceptable. Therefore, the clinical use of the lasers in endodontics is promisable."

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