
A Review on Use of Lasers in Clinical Dentistry

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Abstract:

Improvements in technologies have given the dentists many treatment options. Laser is one of the most captivating technologies in dental practice. As laser offers many advantages over other modalities of treatment, the laser now has become the instrument of choice, in many dental applications. This paper gives an overview of laser dentistry.

Introduction:

Albert Einstein's 1917 theory of spontaneous and stimulated emission of radiation lead Theodore Maiman to develop the first laser (ruby) in 1960.¹ The first laser application to dental tissue was reported in the year 1965 by Goldman et al.² Stern and Sognnaes³ described the effects of the ruby laser on enamel and dentin but the current relationship with dentistry origins from an article published in 1985 by Myers and Myers⁴ describing the in vivo removal of dental caries using a modified ophthalmic Nd:YAG laser. Today laser dentistry is playing a major role in patient care and wellbeing.

Basics of Laser:

LASER is a short form of light amplification by stimulated emission of radiation.⁴ The light energy can induce energy transition in atoms causing the atoms to move from their current state (EO) to the excited state / activated state. This is due to the absorption of a quantum of energy by the atom. This is called 'stimulated absorption'. Because the lowest energy state is the most stable, the excited atom tends to return to normal by spontaneously emitting a quantum of energy called 'spontaneous emission'. This conversion to low energy state can also be achieved by stimulating the activated medium further by a quantum of light at the same transition frequency. This is called 'stimulated emission'. During this process, it releases a photon of the same size as of the released atom, which hits against the adjacent activated atom setting off a chain reaction of releasing photons.⁵ This is the principle on which all lasers work.

Dental lasers are named depending based on the active medium that is stimulated. The active medium can be a gas (e.g. argon, carbon

dioxide), a liquid (dyes) or a solid state crystal rod e.g. Neodymium yttrium aluminum garnet (Nd:YAG), Erbium yttrium aluminum garnet (Er: YAG) or a semiconductor (diode lasers). The active mediums contain atoms whose electrons may be excited to a metastable energy level by an energy source. The active medium may be excited by excitation mechanisms that pump energy into the active medium by one or more of three basic methods; optical (e.g. xenon flash lamps, other lasers), electrical (e.g. gas discharge tubes, electric current in semi-conductors) or chemical. Laser light is unique in that it is monochromatic (light at one specific wavelength), Directional (Low divergence) and coherent (all waves are in a certain phase relationship to each other). These highly directional and monochromatic laser lights can be delivered on to target tissue as a continuous wave, Gated-pulse mode or free running pulse mode.⁶

Continuous waves: the beam is emitted at one power level continuously as long as the foot switch is pressed.

Gated-pulse mode: the laser is in an on and off mode at periods. The duration of the on and off timer is in microseconds.

Free running pulse mode : a very large laser energy is emitted for an extremely short span, in microseconds followed by a relatively long time which the laser is off.

A laser to be useful in clinical practice, it must be able to effectively deliver laser energy to the target site. The existing range of laser delivery systems includes Articulated arms (with mirrors at joints), Hollow waveguides (flexible tube with reflecting internal surfaces).

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Fiber optic delivery systems are presently the delivery system of choice for most lasers as they can deliver laser energy to most parts of the oral cavity and even within the complex root canal system. Fiber optics can deliver laser energy in a forward direction, with minimal divergence from the bare end of a plain tip. This is very useful in cases like cavity preparation or certain soft tissue surgery; however, the minimal divergence means that it is difficult to transfer energy laterally and hence may be limited use for applications such as root canal treatment. Recently a number of fiber optic modifications have been proposed that may be effective in delivering laser energy laterally.⁷ Selecting a delivery system or a fiber optic material that transmits the laser wavelength in use with minimal losses is important for effective delivery of laser energy.⁸

The action of lasers on dental hard and soft tissue as well as on bacteria depends upon the absorption of laser by tissue chromophore (water, apatite minerals, and various pigmented substances) within the target tissue. Better absorption allows for a more efficient photo-thermal sterilization, and ablation.

The principle mechanism of action of laser energy on tissue is photothermal^{9,10} other mechanisms may be secondary to this process (rapid heating of water molecules within enamel causes rapid vaporization of the water and build up of steam which causes an expansion that ultimately over comes the crystal strength of the dental structures, and the material breaks by exploding this process is called ablation) or may be totally independent of this process. The following are the possible mechanisms of laser action:

1. Photo-thermal ablation: This occurs with high-powered lasers, when it used for vaporization of tissues.
2. Photo-mechanical ablation: Disruption of tissue due to a range of phenomena, including such as Shock wave formation, Cavitations etc.
3. Photo-chemical effects: Using light sensitive substances to treat conditions such as cancer.^{11,12}

Factors that influence the effect of lasers on tissue comprise of laser variables of wavelength, pulse energy or power output, exposure time, spot size (and thus energy density), and the tissue variables of physical

and chemical composition (e.g. water content, density, thermal conductivity and thermal relaxation)¹³.

Lasers are classified into several groups^{14,15} : class I (inherently safe); class II and IIIa (where the eye is protected by the blink reflex), class IIIb (where direct viewing is hazardous), and class IV (where the laser power is above 0.5 Watts, and the laser is classified as a extremely hazardous). Most dental and medical lasers are class IV, and thus compliance with safety standards is necessary to protect the dentist, patient and support staff.

Lasers used in dentistry cover a broad range of procedures, from diagnosis of caries to various soft tissue and hard tissue procedures.

Lasers in dentistry today

He-Ne (632.8 nm), Diode laser (635, 670 nm), Diode laser (810, 810 nm), Diode laser (980 nm), Nd:YAG (1064 nm), Ho:YAG (2100 nm), Er,Cr:YSGG (2790 nm), Er:YAG (2940 nm), CO₂ (9300, 9600, 10600 nm) are the lasers extensively studied in dentistry.

USES OF LASERS IN DENTISTRY

Laser doppler flowmetry:

This is an objective, non-invasive, painless, semi-quantitative method, which is more reliable in measuring the blood flow to the pulp. As it does not cause any noxious stimuli, apprehensive or distressed patients accept it more readily than the current methods to assess the pulp vitality. Laser light is transmitted to the pulp by means of a fiber optic probe.¹⁶ Laser Doppler flowmetry uses Helium Neon(HeNe) and Gallium Aluminum (Ga AlAs) as a semiconductor diode lasers at a power of 1 to 2 mW. The scattered light from the moving red blood cells in the circulation will be frequency-shifted, while those from the static tissues remain unshifted. The reflected light composed of Doppler shifted and unshifted light is returned by the afferent fibers and a signal is produced. This technique can be successfully employed for estimating the vitality of the pulp in both adults and children. The tooth to be checked should be isolated. The closer the probe is positioned to the gingival margins, the higher the signal output because of the greater volume of the pulp tissue.¹⁷ At the same time, the potential gingival contamination is also higher.¹⁸ The ideal position to place the probe is 2 to 3 mm from the gingival margin. Different ranges of band width can be set to filter the reflected signal,

with a wider frequency being more sensitive to the moving red blood cells with a wider range of velocity.¹⁹ Theoretically, a wider bandwidth such as 15kHz is preferred, but in case of pulp vitality testing, a much narrower 3 kHz bandwidth may be ideal.²⁰ The end of the LDF probe which contacts the tooth contains both sending and receiving optic fibers, with one of the configuration being one source and two detectors in a triangular arrangement at the probe end.²¹ Due to the pulsatile nature of the blood flow, many studies^{21,22,23} have observed that the LDF recordings in the teeth with an intact pulp blood flow have rhythmic fluctuations or oscillations.

Laser Fluorescence Caries Detection:

Manual probing with an explorer is often an ineffective means to detect caries as the enamel defect may be too small or inaccessible to the explorer tip. In fact, manual probing can actually stimulate caries as a result of iatrogenic damage caused by probe-force. Bitewing x-rays, although effective in revealing advanced stages of decay, are unsuccessful in detecting early caries, especially in the complex anatomy of fissure areas. The diagnodent²⁴ measures laser fluorescence within tooth structure. As the incident laser light is propagated into the site, two-way hand piece optics allows the unit to simultaneously quantify the reflected laser light energy. At the specific wavelength that the diagnodent laser operates, clean healthy tooth structure exhibits little or no fluorescence, resulting in very low scale readings on the display. However, carious tooth structure will exhibit fluorescence, proportionate to the degree of caries, resulting in elevated scale readings on the display of the diagnodent. An audio signal allows the operator to hear changes in the scale values, enabling focus on the patient and not solely on the device.

Lasers in Endodontics:

Laser treatments have been proven to have many advantages over conventional methods in root canal treatments. The laser is an effective tool for the removal of debris, the smear layer and obturation materials, as well as being an effective disinfection tool. The primary use of lasers in endodontics is focused on eradicating microorganisms in the root channel, especially in the lateral dentinal tubuli. This requires a wavelength that shows high transmission through hydroxyapatite and

water. Nd:YAG lasers show the best results in transmission and micro-organism reduction measurements.²⁵ Even at penetration depths exceeding 1.000 μm , 85 % reduction is achieved. The 810 nm diode laser is the second-choice laser source.²⁵ Micro-biological studies have shown that this source provides the second highest micro-organism reduction, approximately 63%. This is nevertheless significantly lower than with Nd:YAG lasers. 980 nm diode lasers may also be an option although high transmission is achieved due to its higher absorption in water. This explains why this laser source, especially at a depth of 1.000 μm , can only achieve 30% to 40% micro-organism reduction. All other wavelengths, such as Er:YAG, Er,Cr:YSGG and CO₂ lasers, are less effective in deep dental tubulus disinfection.²⁵ Their absorption in hydroxyapatite and water is so high that micro-organism reduction would predominantly only take place in the main canal, although reduction through thermal effects can still be detected in the lateral dentinal tubuli up to depths of 300 μm to 400 μm . Er:YAG and Er,Cr:YSGG lasers can however be successfully used to remove organic tissue and smear layers. An X-ray picture of the tooth requiring treatment should be made in order to clearly capture the initial situation after the anamnesis and clinical examinations. Based on the X-ray measuring picture, the root canals of the molars should be prepared to a size of at least ISO 30, and the root canals of all the remaining tooth groups as far as medically necessary (fine dentine chips) and anatomically possible. A standardized physiological salt solution is used as a rinsing medium. The canals are dried with sterile paper tips. The length of the root canal, obtained through the X-ray measuring picture, is transferred exactly to the fiber-optical waveguide to ensure that the flexible 200K μm optical fiber reaches the physiological apex. The fiber is introduced into the root canal to the apex without activating the laser. Only then is the laser activated, and the fiber guided in an apical to coronal direction with rotary movements and in contact with the root canal wall.²⁶ Then root canals are filled.

Lasers in soft tissue and hard tissue procedures in dentistry:

For many intraoral soft tissue surgical procedures, the laser is a viable alternative to the scalpel.

The current applications of laser for dental soft and hard tissue procedure revolve around diode and erbium lasers. Diode lasers are indicated in soft tissue procedures and erbium lasers for both hard and soft tissue procedures. Diode laser wavelength (810-890nm) is highly absorbed by soft tissues and poorly absorbed by tooth and bone.²⁷ Erbium wavelength (2780-2940nm) can be absorbed hydroxyapatite and water and ablate both hard and soft tissues.²⁸ With both the lasers the settings for clinical use for different procedures should be strictly followed according to manufacturers instructions.²⁸

Laser safety:

General safety requirements include a laser warning sign outside the clinic, use of barriers within the operatory, and the use of eyewear to protect against reflected laser light or accidental direct exposure. The selection of the correct eyewear depends on the laser system being used.²⁹ The potentially damaging effect of lasers on the eye depends on their wavelength and thus absorption characteristics. High volume suction must be used to evacuate the plume from tissue ablation. The laser should be in good working condition and should be used and stored as per manufacturer's instruction. It is important to make sure that the equipment is serviced and checked regularly.

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In addition to general safety requirements it is important that the treating dentist takes adequate precautions to prevent injury or damage to adjacent soft and hard tissue or to the pulp and periodontal apparatus. According to Zach and Cohen³⁰, an intra-pulpal temperature increase of approximately 5.5°C can promote necrosis of the dental pulp in 15% of cases, while temperature increases of 11 and 17°C will cause necrosis in 60 and 100% of cases. Several authors have studied the thermal effect of lasers on the periodontal ligament and surrounding bone.³¹ periodontal tissues are not damaged if the temperature increase is kept below 5° Celsius.³² A threshold temperature increase of 7°C is commonly considered as the highest thermal change which is biologically acceptable to avoid periodontal damage.^{32,33}

Conclusion:

Though the lasers were introduced in 1960 by Theodore Maiman it was not until the last decade that lasers have shown rapid strides in technology advances. The emergence of lasers with variable wavelength and the ability to be used for various applications in dentistry have influenced the treatment and treatment planning of dental patients. It has become mandatory for practicing dentists to update themselves on lasers use in dentistry.

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