REVIEW PAPER

Laser in dentistry-Review

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Laser is one of the most captivating technologies in dental practice since Theodore Maiman in 1960 invented the ruby laser. Even though, introduced as an alternative to the traditional halogen curing light, the laser now has become the instrument of choice, in many dental applications. This paper gives an insight on laser in dentistry.

Key words: Laser, Dentistry, History

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Introduction

Laser is the acronym of the words 'Light Amplification by Stimulated Emission of Radiation'. Lasers have come shown a long way since Albert Einstein described the theory of stimulated emission in 1917. Today lasers technology has and is influencing our life in many ways. Its advancements in the field of medicine and dentistry are playing a major role in patient care and wellbeing. This paper gives an overview of the laser's in dentistry. (1)

Historical review

Thought Albert Einstein first postulated Stimulated Emission in 1917, it was not until 1960 that the first laser was invented by Theodore Maimam, a synthetic ruby laser. Initially most of the research in the field of laser was restricted to this laser, with Stern and Sognnaes in 1964(2) reporting that glass like fusion and catering of enamel when subjected to 500-200J/cm^2 of laser energy, they also observe charring of dentine. In 1965 Goldman *et al*. (3) for the first time subjected a vital tooth to laser energy, the paint has experienced no pain and had only minor, superficial damage to the crown. Ruby lasers lost favour soon as it needed far too much energy to effectively denal hard tissue was reported to cause severe thermal to the pulp and collateral damage to adjacent hard and soft tissue due to scattered radiation.

The Nd:YAG laser was developed in 1964 by Bell Telephone Laboratories. Though Nd:YAG Lasers where discovered a year after the ruby laser it was largely overshadowed for a long time by the ruby laser and other lasers of the era (carbon dioxide laser). It was not until 1990 that this laser was available for dental use. Early studies with this laser was in its application for soft tissue procedure as well as inhibition of caries(4).

The carbon dioxide laser was invented by Kumar N Patel in 1964 when working at Bell Telephone Laboratories(5). Carbon dioxide laser was perhabs the first laser that had truly hard tissue and sof tissue application. Weichman & Johnson in 1971(6) was one of the first to use lasers in Endodontics, they unsuccessfully attempted to seal the apical foramen in vitro by means of a high power-infrared (CO 2) laser. Carbon dioxide lasers are well absorbed by water and had the ability be the laser of choice for various dental soft tissue and hard tissue application, however these gas based lasers could not be delivered through optic fiber due to its large wave length that will not fit into the crystalline molecules of the conducting glass and has to be conducted either by a hollow wave guide or an articulate arm delivery system. Also being well absorbed by water they cannot be delivered by fibers or fiber tips that contain water like the quarts fiber tips, as this would disintegrate the fiber. (7)

In 1988, both Hibst and Paghdiwala were the first to describe in detail the effect of the Er:YAG laser on dental hard tissues (7), however it was not until 1997 that this laser obtained US FDA approval for cavity preparation. One of the earliest companies to release Er:YAG lasers onto the market was KaVo (Germany) in 1992. Subsequently, the second erbium laser hard tissue wavelength (Er:YSGG, 2.78 μm) was developed and marketed by Biolase (USA). The erbium family of laser has an emission wavelength of , which coincides exactly with the absorption peak of water, giving strong absorption in all biological tissues, including enamel and dentine and hence are undoubtedly today the most popular soft tissue and hard tissue lasers.

The recent rapid development of lasers, with different wavelengths and onboard parameters may continue to have major impact on the scope and practice of dentistry.

Theory

In 1917, Albert Einstein first theorized about the process which makes lasers possible called "Stimulated Emission." (7) The light energy can induce energy transition in atoms causing the atoms to move from their current state (EO) to the excited state / activated stage. This is due to the absorption of a quantum of energy by the atom. This is called 'stimulated absorption'. (7)

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'. (7)

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. This is the principle on which all lasers work.

Laser basics

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 (8)

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).(1) 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.

- 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.

Laser delivery

For a laser to be useful in clinical practice, it must be able to effectively deliver laser energy to the target site. Early delivery systems were too bulky or cumbersome to use in the oral cavity. Fiber optics were introduced into medicine as early as 1954 by Kapany, who developed the endoscope.(9) Early fiber optic systems had high-energy losses, and were incapable of delivering the mid-infrared laser wavelengths efficiently, and thus most early mid-infrared lasers used alternate delivery systems. The existing range of laser delivery systems includes:

1. Articulated arms (with mirrors at joints) – for UV, visible and infrared lasers
2. Hollow waveguides (flexible tube with reflecting internal surfaces) – for middle and far infrared lasers.
3. Fiber optics – for visible and near infrared lasers

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 useful in cases like cavity preparation or certain soft tissue surgery; however the minimal divergence mean that it is difficult to transfer energy laterally and hence may be of 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 (10, 11)

All the invisible dental lasers are equipped with a separate aiming beam, this coaxial laser beam which can either be either a laser or conventional light.

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, however ever other factors other factors which must be considered before selecting a fiber include: (12)

Mechanism of laser action

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

The principle mechanism of action of laser energy on tissue is photothermal(13), 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 used to vaporization or coagulate tissue through absorption in a major tissue component

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 (14-19) (Using light-sensitive substances to treat conditions such as cancer)

Factors that influence the nature of the effect of lasers on tissue comprise the 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) (20).

Classification

Lasers are classified into several groups: 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 classed as 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. (8, 21)

Lasers used in dentistry

Lasers used in dentistry (Table1) vary from the ultraviolet light, (100-400 nm) to the infra red spectrum (750 nm-1 mm). The visible spectrum lies between these two wavelengths (400-750 nm; and infrared,) Lasers used in dentistry cover a broad range of procedures, from diagnosis of caries or cancer to soft tissue and hard tissue procedure.

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Table.1

Laser type	Wavelength
Argon ion	488-514.5 nm
KTP	532 nm
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

Uses of lasers in dentistry

The rapid development of laser technology has seen its introduction into various fields of dentistry. Some of the present applications of laser in dentist are as follows:

1. Diagnosis
   - Detection of pulp vitality
     - Doppler flowmetry
     - Low level laser therapy (LLLT)
   - Laser fluorescence- Detection of caries, bacteria and dysplastic changes in the diagnosis of cancer
2. Hard tissue applications
   - Caries removal and cavity preparation
   - Re-contouring of bone (crown lengthening)
   - Endodontics (root canal preparation, sterilization and Apicectomy
   - Laser etching
   - Caries resistance
3. Soft tissue applications
   - Laser-assisted soft tissue curettage and peri-apical surgery
   - Bacterial decontamination
   - Gingivectomy and Gingivoplasty

- Aesthetic contouring, Frenectomy
- Gingival retraction for impressions
- Implant exposure
- Biopsy incision and excision
- Treatment of aphthous ulcers and Oral lesion therapy
- Coagulation / Hemostasis
- Tissue fusion - replacing sutures
- Laser-assisted flap surgery
- Removal of granulation tissue
- Pulp capping, Pulpotomy and pulpectomy
- Operculectomy and Vestibuloplasty
- Incisions and draining of abscesses
- Removal of hyperplastic tissues and Fibroma

4. Laser-induced analgesia

5. Laser activation

- Restorations (composite resin)
- Bleaching agents

6. Other

- Removal of root canal filling material and fractured instrument
- Softening gutta-percha
- Removal of moisture/drying of canal

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. 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.

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 Cohen (22), 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 (22, 23). Several authors have studied the thermal effect of lasers on the periodontal ligament and surrounding bone (24-27). The supporting periodontal apparatus is known to be sensitive to temperatures of 47°C, while temperatures of 60°C and above will permanently stop blood flow and cause bone necrosis (28). On the other hand, periodontal tissues are not damaged if the temperature increase is kept below 5° Celsius (29). A threshold temperature increase of 7°C is commonly considered as the highest thermal change which is biologically acceptable to avoid periodontal damage (30-33).

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 may influence the treatment and treatment planning of dental patients.

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