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Dental Lasers - A Review

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Abstract- Theodore Maiman in 1960 introduced the first solid state ruby LASER. Since then LASERs have come a long way with numerous applications in the field of medicine and dentistry. In dentistry LASERs are now in vogue and are now becoming a part of the dentist's armamentarium for endodontic , restorative , periodontal and implant therapies. This paper gives an insight to the basics of LASER physics, various types of LASERs, their interactions with biologic tissues and their uses in Periodontics.

Index Terms- LASER

I. Introduction

LASER is an acronym for **Light Amplification by Stimulated Emission of Radiation.**

Light is a form of **electromagnetic energy** that behaves like a particle and wave. Its basic unit is **photon.** LASER light energy has following characteristics

a) Energy emitted is a light of one color (Monochromatic) thus of a single wavelength.
b) Each wavelength is identical in physical size and shape (Coherent).
c) Photons can be Collimated into an intensely focused energy beam which interacts with the target tissue.
d) Efficiency.

Measurements that define LASER light (Wave of photons) are

i) Velocity, which is speed of light

ii) Amplitude, which is total height of wave oscillation from top of peak to the bottom on a vertical axis. It indicates intensity in wave, larger the amplitude greater the amount of useful work that can be performed.

iii) Wavelength, which is the distance between any two corresponding points on the wave on horizontal axis. It is measured in meters [microns (10^{-6}m) or nanometers (10^{-9}m)]. Frequency is the number of wave oscillation per second.

It is inversely proportional to wavelength. Shorter the wavelength, higher the frequency.

Amplitude and frequency are inversely proportional to wavelength.

Amplification is part of a process that occurs inside the LASER. The inner part of LASER or the components of LASER are as follows:

a) Optical cavity, which is the center of the device. Core of the cavity comprised of chemical elements, molecules or compounds is called active medium. It can be a gas, a crystal or a solid-state semiconductor.

b) Two mirrors, one at each end of optical cavity, placed parallel to each other. One mirror is reflective, which allow photons to be reflected back and forth to allow further stimulated emission. The successive passes through the active medium increase the power of the photon beam. This is the process of amplification. The other mirror is partially transmissive thus allowing light of sufficient energy to exit the optical cavity.

c) Excitation sources either a flash lamp strobe device or an electrical coil, which provides energy into active medium.

d) Cooling system

e) Focusing lenses

f) Other controls

II. Stimulated Emission

When electrical energy is directed, the active medium converts this electrical energy into light energy. A quantum, the smallest unit of energy (of excitation source) is absorbed by the electrons of an atom or molecule (of active medium), causing a brief excitation; then a quantum is released, a process called **spontaneous emission.** According to Albert Einstein's theory an additional quantum of energy traveling in the field of exited atom that has the same excitation energy level would result in release of two quanta, a phenomenon termed **stimulated emission.**

III. Radiation

Radiation refers to the light waves produced by LASER as a specific form of electromagnetic energy.

Ionizing radiations are those with very short wavelengths below 300nm. They are high frequency and have a large photon momentum. It can deeply penetrate biologic tissues.

Non ionizing radiations are those with wavelengths larger than 300nm. They have lesser frequency and less photon energy. They cause excitation and heating of tissues with which they interact. All dental LASERs are nonionizing.

IV. Types of LASERs

1. Hard tissue- LASERs for hard tissue procedures show good absorption by hydroxyapatite and water making it more efficient in ablating enamel and dentine. It causes water to evaporate into steam in tissues and result in micro explosions of hard tissue. Thus, thermal effects are due to micro explosions. (1,2)

a) Er:YAG
b) Er,Cr:YSGG: There is absence of melting, charring and carbonization (char formation)

c) Nd:YAP (Wavelength 1340) It has absorption coefficient in water approximately 20 times greater than Nd: YAG.

2. Soft tissue- LASERs for soft tissue are smaller and less expensive. They considerably have greater applications.
   a) Argon (488nm,514nm wavelength, fiber diameter 300μm,0.05 sec pulse duration, 0.2 second between pulses)
   b) CO2 (5-15 w) It may be absorbed by water component of dental hard tissue which could lead to thermal damage therefore contact with these tissues must be avoided. It leaves a char layer on root surface.
   c) Nd:YAG (1064nm wavelength, 0.2- 1.2mm diameter tips, 3 w power,20 pulses per second) Nd:YAG penetrates water to a depth of 60mm before it is attenuated to 10% of its original strength. Energy is scattered rather than absorbed. If pigmented scattering is twice as great as absorption. Therefore ideal for ablation of hemorrhagic tissue. It penetrates soft tissues to a depth of 2 plus or minus 1. It leaves a char layer on root surface.
   d) Diode(800nm to 830nm,980nm wavelength, fiber diameter 300μm,2-10 w power)
   e) Erbium LASERs in contact mode can be used to cut soft tissue with hemostasis, and then tooth should be protected.

V. LASER DELIVERY SYSTEMS

1. Argon, Diode Nd: YAG (With shorter emission wavelength) - Small flexible quartz optical fibers. For Nd:YAG sapphire and ceramic tips have been developed for contact use(3)
2. Er,Cr:YSGG and Er:YAG (Larger wavelengths) - Special and costly fiber optic delivery system with accompanying helium neon LASER as an aiming beam since wavelength is invisible with peripheral cooling air and water spray for hand piece.
3. CO_2 LASER (Largest wavelength) - Hollow wave-guide that allows beam to be delivered through a flexible tube (4). The smallest diameter of beam (focal point) is nearest the end of hand piece tip beyond which it diverges. This is 3-5mm from target tissue. Divergence of beam beyond focal point results in rapid loss of power density and protects underlying tissue causing protein denaturation and coagulation. Blood vessels up to a diameter of 0.5mm are sealed (5).

VI. LASER EMISSION MODES

1. Continuous mode – Beam is emitted at only one (W) power level for as long as the operator depresses the foot switch.

Examples

a) Diode (used in contact mode with water)

b) CO_2 (used in no contact mode)

2. Gated pulsed mode- There are periodic alterations of LASER energy, much like a blinking light E.g. Diode (Used in contact mode).

All surgical devices that operate in continuous wave have gated pulsed feature.

3. Free running pulsed mode (True pulsed mode) larger peak energies of LASER light are emitted for a short time span usually in microseconds followed by a relatively long time in which the LASER is off. (Can be used for thin tissue)

E.g.

a)Neodymium:Yttrium, Aluminum,Garnet (Nd:YAG) (contact mode, 20 pulses per second)

b) Cr: YAG

c) Er:Cr:YSGG

VII. ERGONOMIC FEATURES OF LASERS

1. Portable
2. Ease of use
3. Few cords or cables

Fiber tip:

A typical soft tissue LASER has a fiber within a hand piece. The end of the fiber may need to be cleaned and stripped to expose the inner core of the fiber to prepare it for clinical use. The fiber management should be efficient and easy and unidose fiber tips(disposable tips) make an efficient setup and conventional delivery system.

The smaller the fiber diameter and higher the power density the more efficient the LASER will cut soft tissue. A unique aspect of working with a dental LASER is that it acts only at the end of the tip. There is no side cutting effect. LASER energy flows freely from the fiber tip of a diode LASER unless the end of the fiber has been initiated or carbonized concentrating the energy at the tip of the fiber. When used in a contact mode a coating of carbonized tissue forms at the tip of the fiber. When this occurs the carbonized tissue absorbs the LASER energy and there is a significant increase in thermal energy delivered to the tissues. As this increased thermal energy is absorbed at the surface of tissue, there is a significant decrease in soft tissue penetration.

Noninitiated fiber tip allows the LASER energy to escape the fiber end freely and flood the irradiated tissue with LASER energy. It can be used to desensitize apthous ulcers.

Calibration of the LASER fiber is critical for successful treatment of periodontal pockets. LASER fiber is adjusted in length to correspond to the periodontal probe charting. The calibration for initial therapy is the depth of the treatment site minus 1mm. This will prevent the fiber from touching epithelial attachment at the bottom of pocket.

VIII. ADVANTAGES OF LASERS

1. Increased coagulation that yields a dry field
2. Better visualization

3. Tissue surface sterilization
4. Reduction in bacterial counts
5. Decreased swelling, edema and scarring
6. Decreased pain
7. Faster healing
8. Increased patient acceptance

Periodontal procedures that are carried out using LASERs:

Removal of calculus, for root etching, cavity preparation, caries removal, bacterial reduction in sulcus and or pocket, gingivectomy, gingivoplasty, de-epithelialization of reflected flaps, removal of granulation tissue, second stage exposure of dental implants, lesion ablation, incisional and excisional biopsies of both benign and malignant lesions, irradiation of apthous ulcers, coagulation of free gingival graft donor site, Depigmentation, assess tooth mobility (6), and measure blood flow(7).

IX. LASER-Tissue Interactions

It depends on LASER wavelength, emission mode, on optical properties of the tissues such as pigmentation, mineral content, water content, and heat capacity.

1. Wavelength decides the degree to which LASER energy is absorbed by the target tissue.

Example:

a) Argon (486nm,514nm)
Well absorbed by pigmented tissues.

b) CO2 (10,600 nm)
High absorption in water
Far infrared

As soft tissue is 75% to 90% of water, 98% of energy is converted to heat and absorbed at surface with very little scatter or penetration (5)

c) Nd:YAG (1064 nm)
Low absorption in water.
Near infrared Absorbed by pigmented tissues.

d) Nd:YAP(1340nm)
Absorption coefficient in water approximately 20 times greater than Nd:YAG.(8)

e) Diode (800-950nm)
Low absorption in water Absorbed by pigmented tissues

f) Er,Cr:YSGG (2780 nm)
Highly absorbed in water and hydroxyapatite.

g) Er:YAG (2940nm)
Highly absorbed in water and hydroxyapatite.

2. The primary interaction of a LASER with target tissue is photo thermal. LASER energy is absorbed by the target tissue and significantly elevates the temperature of the tissues. (9,10).

a) 37 ^{o}C to 50 ^{o}C - the tissue temperature is elevated (Hyperthermia)

b) 60 ^{o}C - the tissue whitens or blanches, which can be seen when an egg white albumin changes from clear to milky during cooking. Proteins begin to denature without vaporization of underlying tissue.
Used in surgical removal of diseased granulation tissue.

c) 70 ^{o}C- produces desirable effect of hemostasis by contraction of wall of the vessel.
Used for coagulation.

d) 70 ^{o}C to 80 ^{o}C - the soft tissue edges can be welded together with uniform heating.

e)100 ^{o}C to 150 ^{o}C - when temperature exceeds 100 ^{o}C intracellular water boils and vaporization of water within tissues occurs causing soft tissue ablation. The solid and liquid components turn into vapor in the form of smoke or steam. Rise in intracellular temperature and pressure leading to cellular rupture as well as release of vapor and cellular debris is termed as 'LASER plume'.

Excision of soft tissue commences at this temperature. In hard tissues ablation does not occur at this temperature, but the water component is vaporized and resulting jet of steam expands and then explodes the surrounding matter into small particles. This mixture of steam and solid is suctioned away. This microexplosion is termed **Spallation**.

f) More than 200 ^{o}C, the tissue is dehydrated and then burned in the presence of air. Carbonization occurs with risk of soft tissue damage. It can be because of high power setting or slow movement of fiber tip across tissue surface.

Exposure of bone to heating at levels equal or more than 47 ^{o}C is reported to induce cellular damage leading to osseous resorption. Temperature levels of equal to or more than 60 ^{o}C result in tissue necrosis. With the possible exception of two wavelengths (Er: YAG and Er,Cr:YSGG) the effect of most dental LASERs on bone is generally detrimental. According to study by Fontana et al (11) temperature changes for different LASERs are as follows:

a) Diode LASER (810nm wavelength, time -9 seconds, power of 800mw, and 1.2 W and 300 µm optical fiber size) the temperature change in bone is 10^{o}C and 11^{o}C.

b) Diode LASER With time of 03 seconds and 600 mw setting there is no bone damage.

c) CO2 LASER the temperature change in bone is 1.4^{o}C to 2.1^{o}C

Nd: YAG LASER the temperature changes in bone are 8.0 degree to 11.1^{o}C

Er: YAG LASER (At pulse energy of 100mJ/ pulse and 10 Hz) there is no melting or carbonization.

Er,Cr:YSGG LASER (5 W and 8 Hz) there is no change in calcium phosphate ratio. No evidence of charring or melting, hence good or osteotomy procedure. (12)

For root surface, Er:YAG LASER would appear to be instrument of choice for effective removal of calculus, for root etching and for creation of a biocompatible surface for cell or tissue reattachment.

X. Precautions during LASER surgery

1. CO_2 LASER beam may be reflected from shiny metal surfaces that may cause inadvertent injury to adjacent tissues. Protective eyewear specific to block wavelength of LASER is used (13).
2. Patients eyes, throat and delicate oral tissues outside the surgical site should be protected from accidental beam impact through use of safety glasses and wet towels or gauze packs. (14)
3. Adequate high speed evacuation should be used to capture LASER plume which is biohazard.

4. Hard tissue should be protected while doing soft tissue surgery such as flat bladed instrument or silver foil between gingiva and teeth. (15)

XI. Wound Healing

Comparative studies have indicated that CO_2 LASER induced wounds healed significantly faster than those created by Nd:YAG LASER, but both heal slower than conventional wound.

Accelerated healing has been reported but generally involves use of low level energy from Helium-Neon diode (Non periodontal applications).

Crespi et al showed indirect evidence of accelerated healing when CO_2 LASER is used in defocused mode. (16)

XII. Conclusion

LASERs are thus a captivating technology and one of the best inventions of the twentieth century. The application of LASERs in Peridontology will definitely alter the clinical practice with numerous uses in the nonsurgical as well as surgical aspects of therapy.

References

[1] Fujii T, Baehni PC, Kawai O, Kwawkami T, Matsuda K, Kowashi Y. Scanning electron microscopic studyof the effects of Er:YAG laser on root cementum. *JPeriodontol* 1998; 69:1283-1290.

[2] Cozean C, Arcoria CJ, Pelagalli J, Powell L. Dentistry for the 21st century? Erbium:YAG laser for teeth. *J Am Dent Assoc* 1997; 128:1080-1087.

[3] Daikuzono N, Joffe SN. Artificial sapphire probe for contact photocoagulation and tissue vaporization withthe Nd:YAG laser. *Med Instr* 1985; 19:173-178

[4] American Academy of Periodontology, Lasers in Periodontics, *J Periodontol 2002; 73:1231-1239.*

[5] Halldorsson T, Langerholc J. Thermodynamic analysis of laser irradiation of biological tissue. *Appl Opt* 1978; 17:3948.

[6] Ryden H, Bjelkhagen H, Söder PO. The use of laser beams for measuring tooth mobility and tooth movements. *J Periodontol* 1975; 46:421-425.

[7] Ryden H, Bjelkhagen H, Söder PO. Intrasulcular laser Doppler readings before and after root planing. *J Clin Periodontol* 1995;22:817-823.

[8] Shafik SS, Kheir AO, Kany F, Omran M. Effect of Nd:YAP laser on dental cementum: A scanning electron microscopic study. J Oral Laser Appl 2002; 2:95-99.

[9] Wigdor H, Walsh JFeatherstone Visuri S et al Lasers in dentistry, Lasers Surg Med1995,16,103-33

[10] Coluzzi DJ Lasers and soft tissue curettage an update, Compendium 2002,23, 1104-11

[11] Fontana CR, Kurachi C, Mendonca CR, Bagnato VS.Temperature variation at soft periodontal and rat bonetissues during a medium-power diode laser exposure.Photomed Laser Surg 2004;22:519-522.

[12] Kimura Y, Yu DG, Fujita A, Yamashita A, Murakami Y,Matsumoto K. Effects of Erbium, Chromium:YSGG laser irradiation on canine mandibular bone. J Periodontol 2001; 72:1178-1182

[13] Pick RM, Pecaro BC, Silberman CJ. The laser gingivectomy.The use of the CO_2 laser for the removal of phenytoin hyperplasia. *J Periodontol* 1985; 56:492-496.

[14] Pick RM, Pecaro BC. Use of the CO2 laser in soft tissue dental surgery. *Lasers Surg Med* 1987;7:207-213.

[15] Powell GL, Whisenant BK, Morton TH. Carbon dioxide laser oral safety parameters for teeth. *Lasers SurgMed* 1990; 10:389-392.

[16] Crespi R, Covani U, Margarone JE, Andreana S.Periodontal tissue regeneration in Beagle dogs after laser therapy. Lasers Surg Med 1997; 21:395-402.

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