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RESEARCH ARTICLE

LASERS – AN ASSET TO ENDODONTICS!!!

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ABSTRACT

Dentistry has incorporated a lot of newer technological advancement to benefit both dentist and patients. In this modern technological era, lasers offer dentist a door to its rewarding, high tech and potentially profitable arena. Currently, various types of laser are available based on their applications. This article explains the basic principle, mechanism and interactions of laser and also its application in dentistry.

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INTRODUCTION

The word LASER stands for "Light Amplification By Stimulated Emission Of Radiation". The application of lasers is almost in every fields of human endeavour from medicine, science and technology to business and entertainment over the past few years. In 1960, Theodore Maiman, developed the first working laser or maser device. Maser is like laser which denotes "Microwave amplification of stimulated emission of radiation". From the ruby crystal a deep red colour is emitted. Over the next few years, researchers studied various possible applications of this visible laser energy. (Robert A. Convissar, 2004) Later studies from 1970s to 1980s found newer other laser devices, such as CO_2 and neodymium YAG (Nd:YAG), which had better tissue interaction with dental hard tissues. (Robert A. Convissar, 2004) The purpose of the article is to highlight the various laser applications developed in dental practice and its clinical application.

Classification of laser: (Donald J.Coluzzi, 2004; Roy George, 2009)

I: According to ANSI and OHSA:

CLASS I: These are low powered lasers that are safe to use, e.g. Laser beam pointer.

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CLASS II A: These are low powered lasers that are hazardous only when viewed directly for longer than 1000 seconds, e.g. He-Ne lasers.

CLASS II B: Low powered visible lasers that are hazardous when viewed for more than 0.25 seconds.

CLASS III A: Medium powered lasers that are normally hazardous if viewed for less than 0.25 seconds without magnifying optics.

CLASS III B: Medium powered lasers that are hazardous if viewed directly.

CLASS IV: These are high powered lasers (> 0.5 W) that produce ocular skin and fire hazards.

II: Based on the wavelength of the beam:

- Ultraviolet rays: 140-400 nm
- Visible light:400-700 nm
- Infrared: 700 to microwave spectrum.

III) Based on the type of laser medium used:

1. Gas laser.
   - Helium Cadmium.

- Helium neon.
- Krypton
- Carbon monoxide.
- Argon.
- Nitrogen.
- Carbon dioxide.

2. Solid laser.
   - Ruby
   - Rhodamine
   - Erbium.
   - Neodynium.
3. Liquid laser.
   - Liquid dye
   - Water vapour
4. Electronic laser
   - Semiconductor
   - Diode

VI) Based on the type of delivery system:

- Flexible hollow wave guide/articulating arms.
- Glass fibre optic cable

V) Based on laser modes:

- Continuous mode
- Gated mode
- Pulsed mode

VI) Based on type of interaction with tissue:

- Contact laser
- Noncontact laser

VII) Based on type of application:

a) Soft tissue lasers-low power about 1 w

- Helium Neon
- Gallium neon
- Gallium arsenide
- Gallium aluminium arsenide

b) Hard tissue laser-high power about 3 w or more

- Argon laser
- CO_2 laser
- Nd; YAG laser
- Er; YAG laser
- Er; YSG laser

History

Table 1. Evolution of laser in dental filed are tabulated below

1960	Albert Einstein	Theory of spontaneous emission of radiation
1960	Maiman	Developed laser or maser
1961	Snitzer	Neodymium laser
1965	Leon goldman	Exposure of vital tooth to laser
1965	Taylor *et al.*	Studied histological effects on pulp
1966	Lobene *et al.*	Use of CO_2lasers in dentistry
1971	Weichman Johnson	lasers in endodontics
1974	Yamamoto *et al.*	Nd:YAG in prevention of caries
1977	Lenz *et al.*	First application in oral and maxillofacial surgery
1985	Shoji *et al.*	Laser aided pulpotomy
1985	Pick *et al.*	First in periodontal surgery
1986	Zakirasen *et al.*	Sterilization of root canals
1994	Morita	Nd:YAG laser in endodontics
1998	Mazeki *et al.*	Root canal shaping with Er:YAG laser

Laser physics

The three common principles of laser arm monochromatic, coherence and collimation. (Roy George, 2009; Theodore Maiman, 1960)

Monochromatic: The light produced by the laser will be of a characteristic wavelength. If the light is produced in the visible spectrum (400-750nm), it will be seen as a beam of intense colour. This property enables the laser to attain high spectral power density.

Coherence: The light which leaves as laser is all perfect in one phase unlike the normal light source, their individual contributions are summated and reinforce each other. A large amount of energy is lost out of phase waves, that cancel each other in an ordinary light source.

Collimation: The laser light beam is collimated to achieve parallelism on leaving the laser aperture, the laser beam collimation, is an important property for good transmission through the delivery systems.

Laser emission modes and delivery systems

Dental laser can be used both in *contact mode* or *non-contact mode*. When the laser tip touches directly the target tissue it is known as contact mode. Whereas in non-contact mode, the laser tip is kept at a distance a few millimetres to centimetres away from the target tissue. (Husein, 2006) Laser emits light energy in three different modes.

1. **Continuous mode:** The beam is emitted continuously at one power level for the length of the time operator presses the foot switch.
2. **Gated – pulse mode:** Similar to a strobe light, the laser energy is switched on and off by opening and closing the mechanical shutter in front of the beam path of a continuous wave every few milliseconds.
3. **Pulsed mode:** Large energies are emitted for a short time, of a few milliseconds usually, followed by a long time when the laser is off.

Lasers utilize different delivery systems, depending on wavelength and the access required at the terminal target tissue. (Husein, 2006; Convissor and Coluzzi, 2004) These include;

A. **Articulated arms:** these have joints made of tubes that allow the arm to bend at the joints where a mirror reflects a beam into centre of the next tube without touching the inner surface of the tube.
B. **Hollow waveguide:** It is a flexible hollow tube that has an interior mirror that reflects the laser energy along this tube and exits through handpiece. These are much thinner than the articulated arms.
C. **Glass fiberoptic cable:** It is even more flexible than a wave guide, smaller in diameter with sizes ranging from 200 to 600 microns. Quartz optical fibre is encased in a resilient sheath.

How laser works

The following components are present in laser (Figure 1) :-

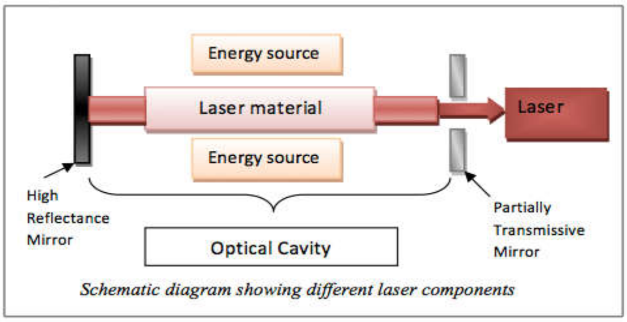

Figure 1. Schematic diagram showing laser components

1.Optical cavity:

- Parallel mirrors
- Lasing medium

2. Pump energy source
3. Cooling system

1. Optical Cavity: It is the core and centre device. It consists of molecules, chemical or compounds elements and is known as lasing / active medium. Based on the nature of active medium, it may be gas, crystal or solid semiconductor, the laser is named. Argon and CO_2 are the two active gaseous medium lasers used in dentistry. Others are solid state semiconductor wafers which are made with multiple layers of metals such as indium, gallium, aluminium, and arsenic or solid rods of garnet crystal with various combinations of yttrium, aluminium, scandium and gallium and then doped with the elements of chromium, neodymium, or erbium. (Walsh, 2003) Another component of optical cavity is two parallel mirrors that are placed on either side of the lasing medium. These parallel mirrors, excite the photons to bounce off and then re-enters the active medium to activate the release of more photons. Thus, the mirrors collimate the light that is photons exactly perpendicular and make them re-enter the active medium, while those off axis leave the lasing process. (Walsh, 2003) Usually, one mirror is totally reflective while the other mirror is partially transmissive and the light that escapes first through the mirror becomes the laser beam.

2: Pump energy source: It is provided by flash lamp or electrical coil which pumps the high energy radiation into the active medium.

3. Cooling System: Most of the remaining energy is converted into heat hence it is necessary to provide some form of cooling, which is provided by water. Thus, finally photons generate a collimated, coherent, and monochromatic laser beam of light.

Laser tissue interaction and its effect

When the laser beam is aimed at tissue the energy reaches the biological interface and any one of four interactions will take place; reflection, transmission, scattering, or absorption. (Walsh, 2003)

Absorption – Specific molecules in tissue known as chromophores absorb the photons. The light energy is then converted into other forms of energy to perform the task.

Reflection – Sometimes the laser beam bounces off the surface with no penetration or interaction. Reflection is usually an undesired effect, but a useful example of reflection is found when Erbium lasers reflect off titanium allowing for safe trimming of gingiva around implant abutments.

Transmission – The laser energy pass through superficial tissues to interact with deeper tissues. The deeper penetration is seen with Nd:a YAG and diode laser is an example of tissue transmission.

Scattering – Once the laser energy enters the target tissue it will scatter in various directions. This phenomenon is usually not helpful, but can help with certain wavelengths biostimulative properties.

Effect of laser irradiation

Photochemical interaction includes

- Biostimulation
- Photodynamic therapy

Photothermal interactions includes

- Photoablation
- Photopyrolysis

Photomechanical interactions includes

- Photodisruption / photodissociation
- Photoacoustic interactions

Photoelectrical interactions includes

- Photoplasmolysis

There are five important types of biological effects that can occur once the laser photons enter the tissue: fluorescence, photothermal, photodisruptive, photochemical, and photobiomodulation. (Guttenberg, 2004; Merchant, 2007)

Fluorescence: When active carious lesion is exposed to 655nm visible wavelength of the Diagnodent diagnostic device, the amount of fluorescence correlates the size of lesion which in turn is useful in diagnosing and treating early carious lesions.

Photothermal: When chromophores absorb the laser energy, heat is generated. This heat helps to perform tissue incision or coagulating blood. Photothermal interactions predominate when most of the soft tissue procedures are performed with dental lasers. Photothermal ablation effect occurs when CO_2 lasers are used on teeth. Most of the procedures produce heat and utmost care must be taken to avoid any thermal damage to the tissues.

Photodisruptive effects (or photoacoustic): Hard tissues are removed through a process known as photodisruptive ablation. The process involves a three interrelated phases such as ionization, plasma formation and shockwave generation. Extremely high power laser light of short-pulsed bursts interacts with water that present in the tissue and from the handpiece causes thermal expansion of water molecules rapidly. This leads to a thermo-mechanical acoustic shock wave which disrupts enamel and bony matrices efficiently. Erbium lasers' had high ablation efficiency that results from these micro-explosions of superheated water present in the tissue, in which their laser energy is predominantly absorbed. Hence bone and tooth are not vaporized but pulverized through the photomechanical ablation process. This shock waves result in the distinct popping sound that is heard at the time of erbium laser use. Thermal damage is not produced, as no residual heat is created when used properly, particularly when the concept of thermal relaxation is considered.

Photochemical: It occurs when photon energy causes a chemical reaction. These reactions are involved in some of the beneficial biostimulation effects.

Photobiomodulation or **Biostimulation** It known as Low Level Laser Therapy (LLLT) and its the ability of lasers to enhance healing, increase circulation, reduce edema, and minimize pain. Various other studies have also demonstrated effects such as increased collagen synthesis, fibroblast proliferation, increased osteogenesis, enhanced leukocyte phagocytosis. The exact mechanism of these effects is not clear but it is stated that it occur mostly through photochemical and photobiological interactions within the cellular matrix and mitochondria. Biostimulation is mainly used to reduce postoperative discomfort and also to treat recurrent herpes or aphthous stomatitis. Is another term used to describe this phenomenon. When laser heats oral tissues certain reversible or irreversible changes occur. Irreversible effects such as denaturation or carbonization result in thermal damage that cause inflammation, pain, and edema. (Frentzen and Koort, 1990)

The thermal effects of laser irradiation are:

Temperature < 60º C

- Tissue hyperthermia
- Enzymatic changes
- Edema

Temperature > 60º C

- Protein denaturation

Temperature > 100º C

- Tissue ablation
- Super heating

Clinical application of lasers in Endodontics

I: Desentization of hypersensitive dentin

After drying the dentin, the laser tip is placed in direct contact with the tooth surface, which is then irradiated for 30 seconds to one minute. HeNe lasers, pulsed Nd:YAG lasers and CO_2 lasers are used. (Gerschman *et al*., 1994; Luciana Chucre and Sebastião Luiz, 2004) Sodium fluoride paste or petroleum jelly is coated on tooth surface and then it is exposed to CO_2 lasers to prevent occurrence of pain and carbonization of tooth surface by laser.

II: Application of laser in pulp therapy

- Deep cavities, hypersensitive cavities and cavity that require sedative treatment are some of the indications for this treatment. It helps to produce mediated effect, pulpal analgesia, seals the dentinal tubules and reduces permeability. On using pulsed Nd:YAG laser, it is necessary to combine the application of black ink to tooth surface and air spray cooling to prevent dental pulp damage resulting from laser energy. (Luciana Chucre and Sebastião Luiz, 2004) When using CO_2lasers, dental tissue must not be exposed to high energy for long periods of time.
- In case of direct pulp capping, high success rate is due to hemostasis, disinfection, sterilization, carbonization and stimulatory effect of dental pulp cells. It causes scar formation in the irradiated area due to thermal effects, which preserve the pulp from bacterial invasion. (Luciana Chucre and Sebastião Luiz, 2004; Gerschman *et al*., 1994) In addition laser minimizes the formation of hematoma between pulp tissue and the calcium hydroxide dressing allowing an intimate contact between the exposed pulp and the dressing.
- Vital pulp amputation, it is one of the highly anticipated laser treatments in because this treatment offer amputation of the pulp tissue at satisfactory level. A CO_2 laser is used for pulpal hemostasis, after which pulp amputation is done with excavator or a bur. (Goldman *et al*., 1964; Klein *et al*., 2005)
- Root canal cleaning and shaping helps in elimination of microorganisms. Thin optical laser fibre [Nd:YAG, Er,Cr:YSGG, argon, or diode) delivers laser beam to the root canal system. (Mensudar, 2014; Gerry Ross and Alana Ross, 2004) Following biomechanical instrumentation, additional cleansing is performed with the help of these lasers.
- Root Canal Irrigation in Combination with laser in case of slightly curved canals as well as wide root canals. The pulsed Nd:YAG laser, Er:YAG laser, or Er,Cr:YSGG laser are used. Solution such as 5.25% sodium hypochlorite or 14 % ethylenediaminetetra-acetic acid (EDTA) must be used along with lasers for effective irrigation.
- It helps to sterilize and disinfect the infected root canals by effectively killing microorganisms. Pulsed Nd:YAG, argon, diode, CO_2, Er:YAG are used.
- It can be used for root Canal Obturation by melting the Gutta percha with Laser heat energy followed by vertical condensation method. Nd:YAG laser can be used for obturation of root canals. It is very time consuming thus it is not practical to use.

Other applications

Use of hard tissue laser: (Sumez *et al*., 2002; Stern and Sognnaes, 1964; Gimbel, 2000)

- Class I, II, III, IV and V cavity preparation
- Caries removal
- Hard tissue surface roughening and etching
- Enameloplasty, excavation of pits and fissures for placement of sealants
- Access to a root canal.
- Root canal preparation including enlargement
- Root canal debridement and cleaning
- Pulpotomy as an adjunct to root canal therapy.
- Apicoectomy – amputation of the root end.
- Root end preparation

Uses of Soft tissue laser: (Pick and Colvard, 1993; Walsh, 2003; Guttenberg, 2004; Merchant, 2007)

- Incision, excision, vaporization, ablation and coagulation of oral soft tissues
- Exposure of unerupted teeth (Operculectomy)
- Fibroma removal
- Incision of soft tissue to raise a flap
- Frenectomy, Vestibuloplasty, and frenotomy
- Gingival troughing for crown impressions, gingivectomy or gingivoplasty and gingival incision and excision.
- Hemostasis.
- Implant recovery.
- Incision and drainage of abscesses.
- Treating conditions like leukoplakia, oral papillectomies, canker sores, herpetic and aphthous ulcers.
- Sulcular debridement - removal of diseased or inflamed soft tissue from the periodontal pocket
- Removal of granulation tissue from bony defects and curettage of the extraction sockets and periapical area during apical surgery.

Laser safety

An adequate safety policy for managing and controlling the risks arising from the use of laser equipment has to be established. The following are the safety measures to be followed during laser use in dental practice. (Parker, 2007)

- Fire and electrical control measures
- Environment protection / control airborne contamination
- Laser protection advisor/laser safety officer
- Laser safety features / procedural safety measures
- Eye protection / personal protective equipment
- Test firing
- Local rules
- Training.

Conclusion

Use of Laser in dentistry has proven to be beneficial in treating numerous dental conditions and also serves as a therapeutic tool in tissue management. The dynamics of laser energy beams pose general risks to non-oral tissues and the immediate surrounding environment and hence necessary safety measures have to be devised to safeguard staff and patients who are involved in dental treatment using lasers. The high quality state of art has been employed in various procedures such as in diagnosis, early caries detection, pulpal blood flow using laser Doppler flowmetry, root canal disinfection and many more applications. It is not only important to realize the various potential uses, it is also necessory to select proper wavelength, to know the laser tissue interactions, its applications, limitations and safety issues.

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