

LASERS AND ITS APPLICATIONS IN CONSERVATIVE DENTISTRY: A REVIEW

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ABSTRACT Lasers were introduced in the field of dentistry with the hope of overcoming some of the drawbacks posed by the conventional methods of dental treatment. Since, its first use for dental treatment in 1964, the use of lasers have increased rapidly in the last couple of decades. Presently, in accordance with their specific wavelength, laser equipments are available on a large scale. This article reviews, laser equipment, laser- tissue interaction, various applications of laser in conservative dentistry, its advantages, disadvantages, hazards of laser and its control measures.

KEYWORDS: Laser, Conservative Dentistry, Hazards

INTRODUCTION

LASER is acronym for 'Light Amplification by Stimulated Emission of Radiation.' Laser light is different from normal regular light. It has a single wavelength and it can be focused in a very narrow beam.¹ Wavelength of laser, determines the effective depth of penetration. Laser functions by producing waves of photons which are specific to each laser wavelength. Properties of laser enable the light beam to penetrate tissue in order to incise the tissue, seal blood vessels and nerves, vaporize diseased tissue. Effects of laser are dependent on the type of laser used and on the type of tissue it is used². The rapid development in the field of laser technology, modern lasers with a wide range of characteristics are now available and being used in the field of dentistry, most importantly in the field of conservative dentistry.^{3,4}

Laser physics

Light is a form of electromagnetic energy that exists as a particle, travel in waves at a constant velocity.⁵ The basic unit of this radiant energy is called a photon; wave of photons travels at the speed of light and it can be defined by two basic properties. The first is amplitude, which is defined as the vertical height of the wave oscillation from zero axis to its peak⁶. The second property of a wave is the wavelength, which is the horizontal distance between any two corresponding points on the wave. Dental lasers have wavelengths in the order of much smaller units by using the terminology of either nanometres (10^{-9} m) or microns (10^{-6} m).⁷ As the waves travel, they oscillate several times per second and this is termed as 'frequency'. Frequency is inversely proportional to the wavelength: The shorter the wavelength, the higher the frequency and vice-

versa.⁸ The atoms will become unstable and will soon spontaneously decay back to ground state, releasing stored energy; this process is called as spontaneous emission. Stimulated emission can occur only when the incident photon has exactly the same energy as the released photon.⁹

Laser device component^{11,12}

All laser devices have the following main constituents:

- a) **Active medium:-** A laser medium can be a solid, liquid or gas. Lasing medium decides the wavelength of emitted light from the laser and the laser is named after the lasing medium Eg: CO₂ laser: If CO₂ is used as active medium/lasing medium.
- b) **External power source:-** It excites or pumps the atom in the laser medium to their higher energy levels. This causes the population inversion. A population inversion happens when there are more atoms in the excited state pumped by the electrical change rather than a non-excited state. Atoms in the excited state spontaneously emit photons of light, which bounce back and forth between the two mirrors in the laser tube. As they bounce within the laser tube, they strike other atoms, stimulating more spontaneous emission. Photons of energy of the same wavelength and frequency escape through the transmissive mirror as the laser beam.
- c) **Optical cavity:-** To contain and amplify the photon chain reaction that results from stimulated emission

in a population of excited atoms, it is necessary to place this reaction within an optical cavity. An optical cavity contains two parallel mirrors placed on either side of the lasing medium. In this configuration, photons bounce off the mirrors and re-enter the medium to stimulate the release of more photons. If some form of energy is provided to continuously pump atoms up to the excited state, the population inversion can be maintained and high intensity light circulating back and forth between two mirrors can be generated.¹¹

- d) **Cooling system:-** Heat production is a by-product of laser light propagation. It increases with the power output of the laser and hence, with heavy-duty tissue cutting lasers, the cooling system represents the bulkiest component. Co-axial coolant systems may be air or water-assisted.
- e) **Mirror:-** The mirror collimates the light, photons hits perpendicular to the mirrors and re-enters the active medium, while those off-axis leave the lasing process. If one mirror is totally reflective and other mirror is partially transmissive, the light that escapes through M1 becomes the laser beam. If our circulating power is 1000W, M1 is 10% transmissive, and then the power returning from M1 is 900W. The lasing medium is located within resonating chamber, which has a cylindrical structure with a fully reflecting mirror (M2) on one side and partially transmissive (M1) mirror at other site. These mirrors are precisely mounted so that they are exactly parallel to one another. This arrangement allows for the reflection of photons of light back and forth across the chamber, eventually resulting in the production of an intense photo resonance within the medium.
- f) **Control panel:-** This allows variation in power output with time and also helps to change wavelength of laser light(multi-laser instruments) and print-out of delivered laser energy during clinical use¹².

Laser delivery:^{11,12}

In clinical practice, a laser must be able to effectively deliver laser energy to the target site. Earlier delivery systems were larger, hand held, several hundred pounds of weight. Technological advances are producing smaller and lighter weight lasers. Eg:- fiber optic delivery system. The existing range of laser delivery systems involves:

- i. **Articulated arms:-** Laser light can be delivered by articulated arms, which are very simple but elegant devices. Mirrors are placed at 45 degree angle to the tube carrying the laser light. The tubes can rotate above the normal axis of the mirrors.
- ii. **Hollow waveguides:-** The laser energy is reflected along this tube and exits through a handpiece at the surgical end with the beam striking the tissue in a noncontact mode. An

accessory tip of sapphire or hollow metal can be connected to the end of the waveguide for contact with the surgical site.

- iii. **Fibre optics:-** The fibre-optic system can be used in both contact or noncontact modes. Mostly it is used in contact mode, directly touching the surgical site. All conventional dental instruments: hand or rotary, physically touch the tissue being treated.

Mechanism of laser-tissue interaction:^{10,13,}

The concept of mechanism of action of laser energy on tissue is photo-thermal, other mechanisms are peripheral to this process.

- i. Photochemical interactions
- ii. Photothermal interactions
- iii. Photomechanical interactions
- iv. Photoelectrical interactions

i. Photochemical interaction:-

It include biostimulation, which described the stimulatory effects of laser light on biochemical and molecular processes that normally occur in tissues such as healing and repair. Photo Dynamic Therapy (PDT), which is the therapeutic use of lasers to induce reactions in tissues for the treatment of pathologic conditions and phosphorescent re-emission or tissue fluorescence, which are used as diagnostic method to detect light-reactive substances in tissues.^{13, 14}

ii. Photothermal interaction:-

It manifest clinically as photoablation or the removal of tissue by vaporization and superheating of tissue fluids; coagulation and hemostasis and photopyrolysis or the burning away of tissues.

iii. Photomechanical interaction:-

It include photo-disruption or photo-disassociation, which is the breaking apart of structures by laser light. Photo-acoustic interactions, which involve the removal of tissue with shock-wave generation.

iv. Photoelectrical interaction

It include photo-plasmolysis which describes how tissue is removed by the formation of electrically charged ions and particles that exist in a semi-gaseous, high-energy state.¹⁵

Classification of laser

1. Lasers can be classified according to its Hardness, Spectrum of light and Material used.¹⁶

2. Lasers are also classified as soft tissue lasers and hard tissue lasers:¹⁷

a) Soft tissue lasers

Soft tissue lasers generally utilize diodes. Clinical applications includes: healing of localized osteitis, healing of aphthous ulcers, reduction of pain and treatment of gingivitis.

Soft tissue lasers in clinical use are:

1. Helium-Neon (He-N) at 632.8 nm (red, visible).
2. Gallium-Arsenide (Ga-As) at 830 nm (infra-red, invisible).

b) Hard tissue lasers

Hard tissue lasers (surgical) can cut both soft and hard tissues. Newer variety can transmit their energy via a flexible fiber optic cable. Commonly used hard lasers are:

1. Argon lasers (Ar) at 488 to 514 nm
2. Carbondioxide lasers (CO₂) at 10.6 micro-meter
3. Neodymium-doped Yttrium Aluminium Garnet (Nd:YAG) at 1.064 micrometer.
4. Neodymium Yttrium-Aluminum-Perovskite (Nd:YAP) at 1,340 nm.¹⁷

3. Classification of laser based on its spectrum:¹⁸

1) UV Light

- a. Spectrum is 100 nm – 400 nm
- b. Use: Not used in dentistry.

2) Visible Light

- a. Spectrum is 400 nm – 750 nm
- b. Use: Most commonly used in dentistry (Argon andDiagnodent)

3) Infrared light

- a) Spectrum is 750 nm – 10000nm
- b) Use: Most dental lasers are in this spectrum.

4. Classification of laser according to the material used:^{19, 20}

A. Gas lasers:

- Argon
- Carbon-dioxide

B. Liquid:

- Dyes

C. Solid:

- Nd:YAG
- Erbium: Yttrium Aluminum Garnet (Er: YAG)
- Diode

D. Semiconductor:

- Hybrid silicon laser

E. Excimers:

- Argon-fluoride
- Krypton-fluoride
- Xenon-fluoride

Laser wavelength used in dentistry

Different wave lengths of laser can be classified into three groups:²¹

1. The UV range (ultra-spectrum approximately 400-700 nm).
2. The VIS range (visible spectrum approximately 400-700 nm).
3. The IR range (infra-red spectrum which is approximately 700 nm) to the microwave spectrum.

Lasers in conservative dentistry

i. For diagnosis of dental caries:

Laser fluorescence:- Laser fluorescence (LF) can be used as an integrated with standard methods for detection of occlusal caries. The portable diode laser-based system explain the emitted fluorescence on the occlusal surface agree with the extent of demineralization in the tooth.²²

Diagnodent (Laser induced fluorescence):- The DIAGNodent is used for caries and calculus detection by emitting a nonionising laser beam at a wavelength of 655nm (at a 90° angle) towards a specific darkened groove on the occlusal surface of a patient's tooth where bacterial decay is suspected, or along the long axis of a root surface to detect the presence of a bacteria-laden calculus. This diagnostic technology, in which the photons of this laser wavelength are absorbed into any existing bacteria in these areas of the patient's tooth, is called Laser induced fluorescence. The instrument's digital display indicates the number of bacteria in this area of the tooth and it may correspond to the extent of decay of the tooth.²³

ii. Laser cavity preparation

The "Laser Drill" has been successful in replacing the conventional bur for cavity preparation. For example, in cases of proximal carious lesions on teeth which have sound occlusal surface, Lasers can be used to prepare a box-only preparation on the proximal surface without involving the sound occlusal surface. In cases of deep caries lesions, cavity preparation can be done using lasers, by decreasing its preparation depth and selective removal of the superficial dentin without harming the underlying pulp. Cases, which require direct pulp capping in case of an accidental non-carious exposure, Er:YAG laser can be used in a de-focussed mode to partially necrose the superficial tissue thus creating a protective barrier around the exposed pulp tissue.²⁴

1. Lasers cut at a point of their tip
2. Lasers should be used in up and down motion
3. Lasers also help in the removal of smear layer

Clinical note: Only Erbium lasers are used for tooth preparation. There should be at least 1mm of clearance

between the end of the laser tip and the surface of tooth structure.⁶

iii. For the treatment of dentinal hypersensitivity:

Dentinal hypersensitivity is characterized as a short, sharp pain from exposed dentin that occurs in response to provoking stimuli such as cold, heat, evaporation, tactility, osmosis, or chemicals. The first mechanism implies the direct effect of laser irradiation on the electric activity of nerve fibers within the dental pulp, whereas the second involves modification of the tubular structure of the dentin by melting and fusing of the hard tissue or smear layer and subsequent sealing of the dentinal tubules. The lasers used for the treatment of dentinal hypersensitivity are divided into two groups: low output power lasers (helium-neon and gallium/ diode) and middle output power lasers (Nd:YAG and CO₂). Low output power laser therapy is used to support wound healing, shows anti-inflammatory effect, has the ability to stimulate nerve cells. Low output laser uses an output power of only 6 mW, which do not affect the morphology of the enamel or dentin surface but allows a small fraction of the energy to reach the pulp tissue.²⁵

iv. Treatment of tooth erosion

Dental erosion is caused by a series of extrinsic and intrinsic factors. Extrinsic factors largely include the consumption of acidic foods. Carbondioxide lasers have been mostly used in the prevention of erosion, due to its efficient interaction with hydroxyapatite crystals. The possibility of increasing the enamel resistance to demineralization after laser irradiation was first demonstrated in 1965 with a ruby laser. Some studies²⁶ showed partial beneficial results with the use of Nd:YAG lasers.

v. For removal of restorative materials

The Er:YAG laser is capable of removing all dental cements and composite resin restorations. Lasers should not be used to ablate amalgam restorations, because of the potential release of mercury vapour. The Er:YAG laser is incapable of removing gold crowns, cast restorations and ceramic materials because of the low absorption of these materials and the reflection of the laser light. These limitations highlight the need for adequate operator training in the use of lasers.²⁷

vi. Etching of tooth surface

Laser etching has been evaluated as an alternative to the acid etching of enamel and dentine. The Er:YAG laser produces micro-explosions during hard tissue ablation that result in microscopic and macroscopic irregularities. These micro-irregularities make the enamel surface micro-retentive and offer a mechanism of adhesion without acid-etching to composite resin. However, it has been shown that adhesion to the dental hard tissues after Er:YAG laser

etching is inferior to that, which is obtained with conventional acid etching.²⁸

vii. Photopolymerisation

Argon laser[488nm of wave length] is a promising source, as the wavelength of the light which is emitted by this laser is optimal for the initiation of polymerisation of the composite resin. Argon laser wavelength activates camphorquinone, a photo-initiator that causes polymerisation of the resin composites. The argon laser radiation is also able to alter the surface chemistry of both the enamel and root surface dentin, which reduces the probability of the recurrent caries. Studies^{28,29} also showed the positive effects of the argon laser compared to halogen light: Its 1) Increased hardness, 2) Increased diametral tensile strength, transverse flexural strength, and compressive strength of the polymerised composite resin, 3) Increased depth of curing 4) reduction in the residual monomer of composite resin.

viii. CAD/CAM technology:³⁰

This technology eliminates the need for conventional intra-oral impression materials. Instead, laser scanners take an optical impression of a prepared tooth and the opposing dentition, and they take a bite registration to produce an interactive three dimensional image. This three-dimensional laser-based imaging technology enables the dentist to take an optical impression and to create a computer file with this data. A virtual model is created, based on the transmitted data and a precise master model is made. The physical model is sent to the laboratory where a final restoration is made.³⁰

Lasers in caries prevention:³¹

Laser irradiation has been considered in preventive dentistry to provide enamel surface resistance to caries: several laser wavelengths, have been proposed for superficial ultra-structural modifications and acid-resistance increase, Sub-ablative CO₂ and erbium family laser irradiation to increase the acid resistance of permanent young healthy teeth could be an effective method of caries prevention. Long term clinical studies are necessary to validate this application before an extensive use of this method in caries prevention.³¹

Advantages of lasers:⁶

- It is painless, bloodless that results in clean surgical field and fine incision
- with precision.
- The risk of infection is reduced as a more sterilized environment is created, as laser kills microorganisms.
- No post-operative discomfort, minimal pain and swelling, generally doesn't require medication.

- Superior and faster healing, offers better patient compliance
- Reduced operator chair time
- Minimal invasive cavity preparation
- Bactericidal effect
- Haemostatic effect
- Increase in the success of direct and indirect pulp capping procedures
- Increased depth of penetration; makes it possible to cure thicker increments of composite resin.

Disadvantages of laser:⁶

- Relatively high cost.
- Requires specialized training for the clinician.
- Modification of clinical technique is required.
- Harmful to eyes and skin of both clinician and patients if exposed adversely.
- No single wavelength of laser will optimally treat all dental diseases
- Lasers don't completely eliminate the need for anesthesia.

Laser hazards:^{4,11,21}

A risk is something which is potential to cause injury. There are a number of risks related to the use of lasers in clinical environment, the most used the laser light itself. The Centre for Devices and Radiological Health (CDRH) of Food and Drug Administration (FDA) of USA sets forth the standards governing the manufacturing of laser equipment in the Code of Federal Regulations (CFR).

1. **Ocular Hazards:** Eye abrasion occurs either by direct emission from laser source or by the iatrogenic reflection of laser light from mirror surfaces used during dental treatment. Dental instruments have ability to create reflections that may result in tissue injury to both the clinician and patient.
2. **Tissue Damage:** Thermal interaction of laser radiant energy with tissue proteins can result in injury to the skin and other non target tissues (oral tissue). Temperature elevations of 21°C above the normal body temperature (37°C) can create cell destruction by denaturation of cellular enzymes and structural proteins, which interrupt basic metabolic processes.
3. **Respiratory Hazards:** It includes the potential inhalation of air borne biohazard: materials are delivered as a result of surgical application of lasers. These secondary hazards belong to a group of 'potential laser hazards' (also called as 'non beam hazards').
4. **Combustion Hazards:** Lasers can cause combustion in the presence of flammable materials. The dental surgical setting can be easily erupted, if exposed to the laser beam which is used by flammable solids, liquids and gases.
5. **Electrical Hazards:** Laser systems include high potential, high power electrical supplies. The most serious accidents with lasers have been electrocution. There are various associated hazards that may be potentially harmful¹¹.
Electrical hazards are grouped as:
 1. Shock hazards
 2. Fire hazards or explosion hazards

Laser hazard control measures:¹¹

According to OSHA guidelines and ANSI standards, for the safe use of lasers in dentistry, Control measures are:

- Engineering Controls:** Engineering controls are planned and built into the laser equipment to give safety. Engineering controls involves enclosures, interlocks and beam stops. Very constructive at removing hazards.
- Personal protective equipment:** All personal within the dental treatment room must wear adequate eye protection, including the patient. Eyewear is an integral part of the protection plan for both the patient and clinical staff. The safety glasses must meet specifications with the most important criteria being optical density. This eyewear has to meet a standard that allows the wearer to be able to gaze directly at the laser beam.
- Procedural controls:** Some dental procedures require general anesthesia. If general anaesthesia is used during dental procedure, in place of the standard PVC intubation tube, a red rubber or silastic tube should be used. A wax spatula or periosteal elevator should be used to shield the tissue near the teeth. Always check the foot switch before each procedure to make sure it does not get stuck in position while operating. Many laser accidents can be easily avoided by simply following the recommended control measures.

CONCLUSION

Lasers provide the clinicians, the ability to better care for patients with advanced diagnostic methods and improved treatment techniques. Further scientific and medical research in the development of advanced laser systems, will revolutionise its clinical use much more significantly in the field of conservative dentistry.

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