Lasers an Inevitable Tool in Modern Dentistry: An Overview

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INTRODUCTION

Lasers range from those activated by natural gases, elements, molecules or man-made crystals to those that measure distance to the moon, create laser-guided warfare and record the price of our own groceries. Over the past several years one has seen a strong emergence of lasers in the field of dentistry. Lasers are not, however, new to the field as some of the in vitro studies report back to 1960s but it was not until the early 1980s till the lasers saw their first use in the clinical practice. When used efficaciously and ethically lasers are an exceptional modality of treatment for certain clinical conditions that dentist or dental surgeons treat on daily basis. Regardless of the wavelength used lasers in dentistry offer a wide variety of advantage:

1. Lasers seal the blood vessels and they offer a dry operating field and excellent visibility.
2. In addition seal the lymphatic vessels which yield minimum postoperative swelling.
3. With the use of lasers pain is reduced to absent in 90%.
4. A laser offers the ability to negotiate curves and folds in the oral cavity.
5. They cause less chance for mechanical trauma, minimal scaring and sutures are rarely needed.
6. They cause reduction in the bacterial count and in some areas may sterilize the field as well. Blum JF et al (1997)1 found that the antibacterial effect of the lasers are frequency dependent as he found that only a frequency of 30 Hz inhibited the growth of Streptococcus mitis using a Nd: YAP laser. Kranendonk A et al (2010)2 did an in vitro study, in which Nd: YAG laser used was found to be effective for total killing of the six tested periodontal pathogens.
7. Increased patient acceptance due to minimum postoperative discomfort.

History and Development of Lasers

Light has been used as a therapeutic agent for many centuries and this use of light for various therapies is referred to as phototherapy. In ancient Greece the use of sun for the exposure of the body was referred to as heliotherapy. The earliest use of photochemotherapy dates back to 1400 BC when Indians used a drug called psoralens, which was obtained from a plant and was used to treat vitiligo. A lotion was applied to the skin, which was then irradiated with sun, and in 1974 it was found that psoralens combined with UVA radiation (PUVA) is effective in treatment of many diseases. LASER (light amplification by stimulated emission of radiation) was initially known as MASER (Microwave amplification by stimulated emission of radiation). Nobel prize for the development of LASER was given to Townes, Basov and Prokhorov in 1964. Credit for the development of the theory of spontaneous and stimulated emission of radiation however, is generally given to Einstein for his treatise ‘zur quantum theorie der stralung’ which was initially published in 1963.

The first laser to be developed was the ruby laser, which emitted light of 0.694 µm in 1960 and surprisingly the second laser to be developed was the neodymium laser in 1961. But ironically all the research for its usage in the dental field was being carried on the ruby laser and had dental researchers focused on the neodymium lasers earlier laser dentistry must had progressed to the present status 10 years ago. Ruby laser was not effective in dental field because of its high thermal effects on the dental hard tissues.

The first report of the laser interaction to the vital human tooth appeared in 1965 when Leon Goldman applied two pulses of ruby lasers to the tooth of his brother, Bernard, who was a
dentist. According to their report the dental laser patient experienced no pain, with only superficial damage to the crown. Ironically, the first laser dentist was a physician and the first laser dental patient was a dentist. Then from 1960-1980 dental researchers continued to search for many other different types of lasers that might be effective for the application to the dental hard tissues. Then came the CO₂ lasers with a wavelength of 10.6 µm and it is well absorbed by enamel. Within the field of medicine ophthalmology was the first branch to successfully use ruby laser for the surgical treatment of retina in mid-1960’s.

**Laser Physics**

Photons are the basic unit or quanta of light. When a photon strikes a atom, electron within the atom jump to a higher energy level (e?). Thus, this atom is now pumped to an excited state. This atom is now unstable and will try to return to its resting state thus, releasing the stored energy in the form of emitted photons. This type of emission is known as spontaneous emission. But in lasers there is something known as stimulated emission and this process of lasing occurs when an excited atom can be stimulated to emit a photon before this process occurs spontaneously. This occurs when the incident photon has the same energy or wavelength as the released photon. So, when the incident photon of the same energy or wavelength enters the electromagnetic field, it triggers the decay of excited electron to a lower energy state. Thus, the result of stimulated emission is two photons of identical wavelength traveling in same direction. The release of second photon is time locked to the release of the first so that the two photons oscillate together in the same phase. For lasing to occur there should be population inversion, which means that in a collection of atoms if there are more electrons in a pumped state or an excited state rather than remaining in a resting state.

**Laser Components and Beam Generation**

Basic components of a laser include:
1. Lasing medium
2. Optical cavity
3. Pump energy source
4. Cooling system

Lasing medium (CO₂, Nd, Argon) is placed inside an 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 the optical cavity. An optical cavity consists of mirrors placed on the either side of the lasing medium. Because of this the photons bounce on the mirrors and remain in the medium to stimulate the release of more and more photons. Energy source is applied to provide some form of continuous energy to pump up the atoms in an excited state. Because this process is not 100% efficient and some energy is converted into heat it is necessary to provide a coolant. If our circulating power is 1000 W and the transmissive mirror is 10% transmissive then the laser beam is of 100 W.

**Beam Profile and Spot Geometry**

It is the beam profile that has the effect on the target and there are two types of beam profile:
1. Gaussian mode or fundamental mode also referred to as TEM₇₀ mode or transverse electromagnetic mode 00.
2. Donut mode (TEM₁₀) which has a cold spot in the center.

**Power Density**

Power density is simply the concentration of photons in a unit area. Different power densities are achieved from different combinations of power and the spot size. If a power of 10 W is used with a spot size of 2.0 mm then a PD of 318 W/cm² is achieved. If the focal spot is decreased by a factor of ten to 0.2 mm then the PD increases by a factor of hundred to 31800 W/cm².

The term focused and defocused when working with lasers refers to the position of the focal point in relation to the tissue planes. When working on tissues the lasers should always be used either with the focal point positioned at the tissue surface (in focus) or positioned above the tissue surface.

**Gating and Pulsing**

All surgical lasers have a mechanical shutters which are positioned at the beam path just like a camera, the opening and closing of which is controlled by a timing circuit. The time sequence is activated when the user steps on the foot pedal or in some units pressing the button on the hand piece. Single pulse can have a duration of 0.05, 0.1, 0.2 and 1 second. The beam coming out of the lasers can be modulated into any of the three varieties namely:
1. Continuous: That is same intensity of beam is delivered for full-length period of time right from start to the end.
2. Gated: In this the beam is increased from normal and then maintained for a short period of time and then further returned to normal. This process is repeated as many times.
3. Pulsed: In this the beam is increased in intensity from normal but not maintained to the height unlike gated but instead brought down to normal.

**Classification of Lasers**

Lasers are named for the contents of the active medium and there state of suspension, e.g. CO₂ gas laser or argon ion gas laser. Dental lasers fall into two basic categories:
1. Those, which work solely on noncontact mode either focused or defocused, e.g. CO₂ and erbium laser.
2. Those that work either in contact or noncontact mode, the contact mode being focused and the noncontact mode being defocused. This group includes lasers given by fiber optics, e.g. Argon, Nd: YAG and Ho:YAG.

**Noncontact Lasers**

This includes CO₂ lasers as they work primarily by noncontact mode which can be either focused or defocused. The focused mode is when the laser beam hits the tissue at its focal point or its smallest diameter and the diameter in turn is dependent upon
the lens used. Most CO₂ lasers have lenses that can focus the beam to a spot size ranging from 0.1 mm to 0.35 mm or larger. This focused mode is also called as cut mode. The other mode is called as defocused mode in which moving the focal spot away from the tissue plane defocuses the beam and thus, the beam size that hits the tissue plane has a greater diameter thus covering a wide area of the tissue to be vaporized.

In incisional and excisional biopsy CO₂ laser is used as a precise cutting tool. In excisional biopsy the surgical outline is carefully mapped including normal borders at all outline. CO₂ laser can also be used for laser peel or whitening procedure, which is usually done to remove vesiculobullous lesions or other lesions that involve larger surface areas.

Ablation is another noncontact surgical application of laser. It is the term used to describe the method of ‘painting away’ a lesion of tissue by laser. In this the tissue is simply vaporized.

**Fiber Optic Lasers**

Lasers with wavelength shorter than 2,500 nm can be delivered through fiber optics. Of this category includes Nd: YAG and Ho: YAG lasers. The fibers act to direct the photons along the long axis of the fibers and as photon hits the outer surface of the fiber they are reflected into the fibers by a reflective coating, thus some photons have a different travel distance as they bounce back along the inside of the fibers. Standard fibers measure about 6 to 12 feet in length and come in variety of diameters ranging from 60 to 600 µm. As the fiber diameter decreases the potential energy density increases, fiber flexibility increases and potential of lateral fracture of the fiber decreases. Special ‘sapphire’ coated tips are there that act as the interactive material. This focused mode is also called as cut mode. The other mode is called as defocused mode in which moving the focal spot away from the tissue plane defocuses the beam and thus, the beam size that hits the tissue plane has a greater diameter thus covering a wide area of the tissue to be vaporized.

**Laser Interaction with Biological Tissues**

The essential elements of laser light that determine its interaction with matter are as follows:

1. **Wavelength of the emitted energy by the laser.**
2. **Power density of the beam.**
3. **Temporal characteristics of the beam energy like continuous vs pulsed delivery, pulse rate and pulse duration.**

   Tissue elements that exhibit a high coefficient of absorption for a particular wavelength are called chromophores like hemoglobin, hemosiderin and melanin. When considering the hard tissues like enamel, dentin and bone it is the hydroxyapatite that acts as the interactive material.

**Tissue Effect**

If radiation energy (any amount) is absorbed by the tissue there are four basic types of responses that can occur like:

1. **Photochemical interaction**
2. **Photothermal interaction**
3. **Photomechanical interaction**
4. **Photoelectrical interaction**

**Photochemical Interaction**

This type of interaction includes the interaction of the beam with the chemical process of the tissue and can be further subdivided into:

a. **Bistimulation:** It describes the stimulatory effect of laser light on biochemical and molecular processes that normally occur in tissue like healing and repair.

b. **Photodynamic therapy:** It is the therapeutic use of lasers for the treatment of pathological conditions. Kingsbury JS et al (1997)² suggest that photodynamic therapy possesses significant potential in elimination of premalignant tissues. This could be beneficial in treating potentially premalignant lesions, such as oral leukoplakias and useful as an adjunct therapy in removal of areas of field cancerization adjacent to cancer sites. According to Griffiths CE et al (2000)³ PUVA or UVB when used in narrow band of 311 nm and when combined with retinoid appeared to be more effective in the treatment of psoriasis.

c. **Fluorescence:** Which can be used to detect light reactive substances in the tissues.

**Photothermal Interaction**

It manifests basically:

a. **Photoablation:** Which is nothing but removal of the tissue by vaporization and superheating of the tissue fluids, coagulation or hemostasis.

b. **Photopyrolysis:** It is burning away of the tissues.

Cho SB et al (2010)⁴ used Q-switched neodymium-doped yttrium aluminum garnet (Nd: YAG) lasers and stated that they are popular nonablative and selective photothermolysis therapies for pigment disorders.

**Photomechanical Interaction**

It includes:

a. **Photodisruption or photodissociation:** Which is nothing but breaking apart of the structure by laser light.

b. **Photoacoustic:** Which involves removal of the tissues with shockwave therapy.

**Photoelectrical Interaction**

It includes:

a. **Photoplasmolysis:** Which describes how tissue is removed through the formation of electrically charged ions.

   Thus, noncontact surgery relies solely on pigments and waters present in the tissue that are responsible for the absorption model of each wavelength.

**Laser Safety in Dental Practice**

Prior to any clinical and research application of lasers, clinicians and researchers should participate in a formal comprehensive
laser training program to ensure their safety and safety of staff and patients. Lasers according to the safety standards are broadly divided into four basic types by the ANSI (American National Standards Institute) and OSHA (Occupational Safety and Health Administration) namely:

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Low-powered lasers that are safe to use</td>
</tr>
<tr>
<td>II a</td>
<td>Low-powered visible lasers that are hazardous only when viewed directly for longer than 1000 seconds (15 min approx)</td>
</tr>
<tr>
<td>II b</td>
<td>Low-powered visible lasers that are hazardous only when viewed directly for longer than 0.25 seconds</td>
</tr>
<tr>
<td>III a</td>
<td>Medium-powered lasers that are normally not hazardous if viewed for less than 0.25 seconds without magnifying optics</td>
</tr>
<tr>
<td>III b</td>
<td>Medium-powered lasers that can be hazardous if viewed directly</td>
</tr>
<tr>
<td>IV</td>
<td>High-powered lasers (&gt;0.25 W) that produce ocular, skin and fire hazards</td>
</tr>
</tbody>
</table>

The types of hazards that can be encountered by lasers in dentistry are broadly classified into:
1. Ocular hazards
2. Tissue damage
3. Respiratory hazards
4. Fire and explosion
5. Electric shock

Ocular Hazards
Damage to the eyes (retina or corneal burn) can occur either from the direct emission of laser or by reflection from a mirror like surface, e.g., dental instruments, therefore the use of carbonized or nonreflective instruments has been recommended along with safety goggles during treatment.

Tissue Damage
Laser induced damage to the skin and other nontarget tissues can result from a thermal interaction of the radiant energy with the tissue proteins.

Respiratory Hazard
These can occur due to environmental spillage of the laser and potential inhalation of the airborne biohazardous material that may be released because of surgical application of lasers. This can be taken care of by using:
1. Surgical laser smoke evacuator.
2. Laser filtration masks, which remove particles as small as 0.3 µm with at least 80% efficacy.

Fire and Explosion
In presence of inflammable material lasers may pose significant hazards. These flammable solids, liquids or gases used within the surgical setting can be easily ignited if exposed to surgical beam.

Electrical Hazards
Because class IV surgical lasers use very high power, they can be associated with electrical hazards like electric shock hazards, electric fire hazards or explosion hazards. If while lasing the soft tissues the tooth has to be protected, then a blackened or anodized instrument like wax spatula or periosteal elevator can be used.

According to Sahar-Helft S (2009)5 laser technology is being developed very quickly, as well as a better understanding of laser interaction with biological tissues, has widened the spectrum of possible applications.

Application of Lasers in Dentistry

1. Biopsy (incisional and excisional): An important point of consideration here is the amount of the tissue damaged laterally to the laser incision in respect to histopathological examination and wound healing. Goharkhay K et al (1999)6 mention that diode laser has a remarkable cutting ability and a tolerable damage zone, which clearly shows that the diode laser is very effective and because it has excellent coagulation ability it is a useful alternative in soft tissue intraoral surgery.
2. Tongue lesions: Lesions on the tongue when removed by conventional methods bleed like hell and this can be minimized by laser removal of the tongue lesions, which gives a bloodless feeling. Average indicated power setting is 3 to 12 W depending upon the size of the lesion.
3. White lesions, vesiculobullous lesions and premalignant lesions: According to Zakrzewska JM (1996), Flynn MB, White M and Taban R in 1988 were the first persons to use CO2 lasers in the treatment of premalignant lesions like OLP, benign MMP, sublingual keratosis and various hyperkeratotic growths. Basically, two types of procedures can be performed:
   a. Laser peel procedure also known as surface ablation.
   b. Surface vaporization or ablation of the lesion down to the required depth.
Gooris PJ (1999)8 used CO2 lasers effectively to peel off leukoplakias of the lower lip and found that there was complete reepithelization after 4 weeks with minimal scar and with normal lip function. Meister J et al (2010)9 used a new light guide technology with Er:YAG for successful clinical treatment of oral hyperkeratosis especially oral leukoplakias with splendid results.
Kingsbury JS et al (1997)2 suggest that photodynamic therapy possesses significant potential in elimination of premalignant tissues. This could be beneficial in treating potentially premalignant lesions, such as oral
leukoplakias and useful as an adjunct therapy in removal of areas of field cancerization adjacent to cancer sites. According to Zakrzewska JM (1996)7 verrucous leukoplakia has a high rate of malignant transformation and CO2 lasers are used effectively for the treatment of premalignant lesions.

4. **Aphthous ulcers:** One of the most remarkable laser benefits is the relief of painful symptoms associated with aphthous ulcers. The laser is brought into highly defocused mode where minimal energy is delivered to the site.

5. **Treatment of salivary gland pathologies specially mucocele and ranula:**

6. **Herpetic lesions:** Lasers especially CO2 are used for symptomatic relief of herpetic lesions. The technique is exactly the same as used for aphthous ulcers.

7. **Coagulation:** Lasers are used for coagulation of bleeding areas, coagulation of soft tissue donor sites or other small oral bleeding areas. For active bleeding areas the laser of choice in the order are: Argon > Nd:YAG > Ho:YAG.

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8. **Frenectomy:** There is no better use of lasers other than for maxillary midline or lingual frenectomy. In this 4 to 5 W of power in a highly defocused mode from 35 seconds to 2 to 3 minutes is used. There is pain-free healing and the problem of removal of the suture from the nonkeratinized mucosa is also not there.

9. **Crown lengthening:** Lasers can be used for crown lengthening. Power setting of 3 to 6 W with the beam moving from focused to defocused mode as necessary.

10. **Gingivectomy:** To treat overgrowth pockets or hyperplasias of various causes. Beam power of 4 to 10 W depending on the thickness of the tissue and is used in defocused and focused mode with a spatula being used to protect the tissue. De Oliveira Guaré R (2010)11 stresses that a diode laser was used as an effective and safe method to remove the patient’s overgrown gingival tissue.

11. **Gingivoplasty:** Lasers used in about 2 to 5 W depending upon the size of the lesion can be used to remove small tissue abrasions.

12. **Preprosthetic surgery:** For removal of epulis, inflammatory papillary hyperplasia, vestibuloplasty or other preprosthetic surgical needs.

13. **Malignant lesions:** A focused mode is usually used at a power setting ranging from 4 to 10 W. A potential advantage hypothesized is that the chance of seeding the lesion and subsequent metastasis may be minimized or eliminated because lasers have the ability to seal the blood vessels and the lymphatic.

14. **Hemorrhagic disorders:** Lasers have been of very much importance to treat patients who have various intraoral lesions compounded by hemorrhagic disorders like:

a. Hemophilia
b. Idiopathic thrombocytopenic purpura
c. Sturge-Weber syndrome
d. Hemangiomas

Saafan AM and Salah MM (2010)12 mention that ND:YAG lasers are very useful in managing infantile hemangiomas especially in head and neck regions.

Goharkhay K et al (1999)6 mention that diode laser has a remarkable cutting ability and a tolerable damage zone, which clearly shows that the diode laser is very effective and because it has an excellent coagulation ability it is a useful alternative in soft tissue intraoral surgery.

15. **Hypersensitivity:** Lasers have proven to be effective in reducing or completely eliminating temperature sensitivity especially due to cold. It is used in highly defocused mode at a low indicator power setting (1-2 W). Zhang C et al (1998)13 mention that CO2 laser is a useful method of treatment of cervical dentinal hypersensitivity without thermal damage to the pulp. González-Rodríguez A et al (2010)14 demonstrate that CO2 and diode laser irradiation of the enamel surface can both increase fluoride uptake.

16. **Exposure of implants (Stage II):** Lasers work especially well for uncovering implants whether they are single or multiple fixtures. This is done in a defocused mode at a power setting of 3 to 6 W in a circular motion. This is also called as a cookie-cutter approach.

17. **Hard tissue like tooth cutting:** Cozean C et al (1997)15 mention that Er:YAG lasers can be used to treat dental hard tissues and is a safe and effective method for caries removal, cavity preparation and enamel etching.

Whitters CJ and Strang R (2000)16 say that a novel pulsed CO2 laser is an effective method for cutting cavities in the teeth. They say that using this there was no charring or surface cracks on the lased enamel surface using microscopic technique.

18. **Bony surgeries:** There have been many attempts to try using lasers for the bony surgeries. There are conflicting evidences in the literature. According to Friesen LR et al (1999),17 currently the most common laser used for dental procedures are the Nd:YAG and the CO2 lasers. Paulette S (1998)18 mentions that the application of Nd:YAG and the CO2 lasers to the areas where soft tissue closely approximates the bone may transfer sufficient energy to the bone to cause damage and/or necrosis.

19. **Vitality checking:** Evans D et al (1999)19 state that laser Doppler flowmetry is an effective noninvasive method to check the pulpal blood flow and found it to be a reliable method of assessing the pulpal status of traumatized anterior teeth.

20. **Laser-assisted tooth whitening:** Reyto Y (1998)20 states that cosmetic surgery and adhesive dentistry has not only increased patient self-esteem and confidence but also increased an awareness of the value of healthy teeth and gums.
21. **Root canal treatment**: Roper MJ et al (2010)\(^{21}\) states that the erbium laser are equivalent to rotary files in the coronal and middle thirds but not in the apical thirds of the root canal system.

**CONCLUSION**

In the near future the role of lasers in the dental treatment will rise tremendously and to meet this foreseen requirement it is really necessary for upcoming dentists to have a detailed knowledge of the physics and the interactions involved in lasers. Cobb CM et al (2010)\(^{22}\) mention the usage of lasers have become a highly dependable and desirable tool replacing the traditional scalpel-based surgeries for periodontal needs. This is an excellent mode that can be used for various applications ranging from soft tissue to hard tissue. Weesner BW (1998)\(^{23}\) says that there has been an explosion in research, articles and case reports about laser therapy in recent years. The future is promising and the literature is exciting, but sometimes conflict in findings. Laser may seem to have a much greater role in the future than is now realized.

**REFERENCES**