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A Review- Basic of Laser and Its Role in Periodontics: Part I

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Abstract: *The use of dental lasers for treatment of periodontal diseases has been the area of interest in the recent years. First experiment for dental application in the 1960s, the use of laser has increased rapidly in the last couple of decades. This paper describes the fundamentals of laser and the basic elements of a device. The principles of laser-tissue interaction, photo-thermal events, and different absorption characteristics of dental tissues by laser energy are discussed. This paper has been divided into two parts, first part describes about the basic part of lasers and the second part will describe about the role of lasers in periodontal therapy.*

Keywords: *Laser, Periodontics, Implant, Er:YAG, Nd:YAG.*

I. Introduction

Mainman developed the first laser in 1960 which was based on Albert Einstein's theory stimulated emission of radiation.[1] He used crystal medium of ruby which emit radiant light when stimulated by energy. In 1961, Snitzer developed prototype for Nd:YAG laser.[2]

In the medical field, lasers have been successfully used since the mid-1960s for precise photocoagulation of the retina. Thus, ophthalmologists were the pioneers of laser application[3] and now the CO_2, Nd:YAG, Er:YAG, Er,Cr:YSGG, Ho:YAG and diode lasers are available for dental and medical surgical specialities.[4,5]

Periodontal therapy utilizing a laser has been reported as a monotherapy,[6] as an adjunct to scaling and root planing, for root debridement combined with surgical or nonsurgical therapy[7]and to perform surgical laser-assisted new attachment procedures (LANAP).[8,9]

Historical Background[10,11,12]

1917 (Albert Einstein)- Stimulated emission
1959 (Schalow and Townes)- Principle of MASER
1960 (Theodore Mainman)- Prototype of ruby laser
1961 (Javan, Bennett, Harriott)- Constructed the first gas laser and continuously operating laser.
1962 (Robert N. Hall)- demonstrated the first *laser diode* device, made of gallium arsenide.
1965 (Goldman)- for tattoo removal and treatment of caries.
1971 (Hall, Jako et al)-Tissue reactions to laser light and wound healing:
1972 (Stern, Sognnaes)- laser inhibition of dental caries.
1974 (Geusic et al)- Used Nd:YAG laser
1985 (Frame, Pick & Pecaro)- Pioneer of oral surgical application of CO_2 laser.
1988 (Hibst & Paghdiwala)- Er:YAG laser
1989 (Myers & Myers)- used modified Nd:YAG laser for removal of dental caries, he also suggested its use in soft tissue surgery.
1991 (Midda et al.)- Nd:YAG in periodontal surgery.

II. Types Of Laser

Laser are of various types depending on its spectrum of light, its active medium and type of tissue on which it works such as soft tissue and hard tissue laser.[13] The characteristics of a laser depend on its wavelength.[14,15](Fig-1)

Table-1: Types of laser and their wavelength[14]

LASER TYPE	ACTIVE MEDIUM	WAVELENGTH
Excimer Lasers	Argon fluoride (ArF) Xenon Chloride (XeCl)	193nm 308nm
Gas Lasers	Argon Helium Neon (HeNe) Carbon Dioxide (CO_2)	458nm-515nm 637nm 10,600nm
Diode Lasers (Semiconductor)	Indium Gallium Arsenide Phosphorus (InGaAsP) Gallium Aluminum Arsenide (GaAlAs) Gallium Arsenide (GaAs) Indium Gallium Arsenide (InGaAs)	655 nm 670–830 nm 840 nm 980 nm
Solid State Lasers	Frequency-doubled Alexandrite Potassium Titanyl Phosphate (KTP) Neodymium:YAG (Nd:YAG) Holmium:YAG (Ho:YAG) Erbium, chromium:YSGG (Er,Cr:YSGG) Erbium:YSGG (Er:YSGG) Erbium:YAG (Er:YAG)	337 nm 532- 632 nm 1,064 nm 2000-2200 nm 2,780 nm 2,790 nm 2,940 nm

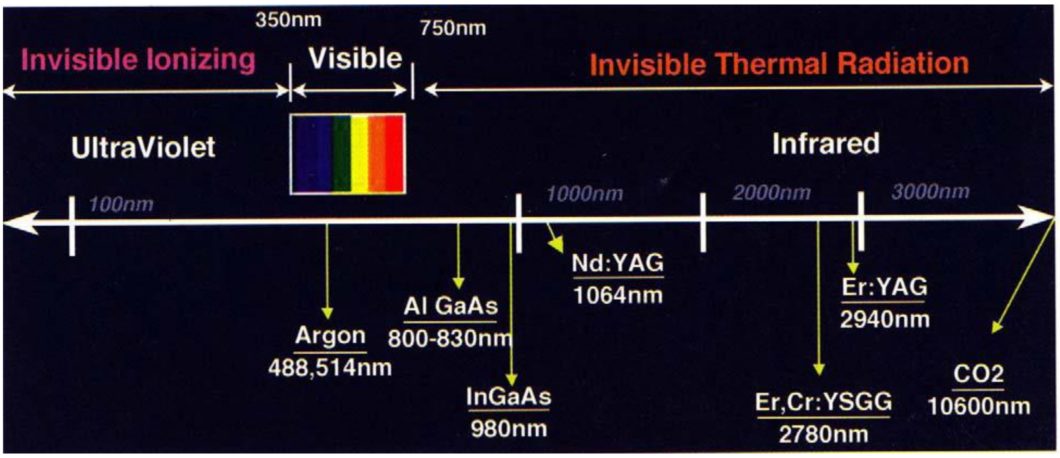

Fig-1: A portion of the electromagnetic spectrum showing dental laser wavelengths being used for treatment.

III. Components Of Laser Device

Basic components of laser device are:[3,16] (Fig-2)

1. **Gain medium/ laser medium**- Can be solid, liquid or gas and is pumped by an external energy source.
2. **Resonating chamber/ Laser tube with two reflecting mirrors**- One fully reflective and the other one partially transmissive, which are located at either end of the optical cavity.
3. **Power source/ Energy source**- It can be mechanical, chemical and optical which excites or "pumps" the atoms in the laser medium to higher energy levels.

Laser light is produced by pumping (energizing) a certain substance or gain medium, within a resonating chamber. The various laser systems are usually named after the ingredients of the gain medium. Three factors are important for the final characteristics of the laser light: composition of the gain medium, source of pump energy, and design of the resonating chamber.

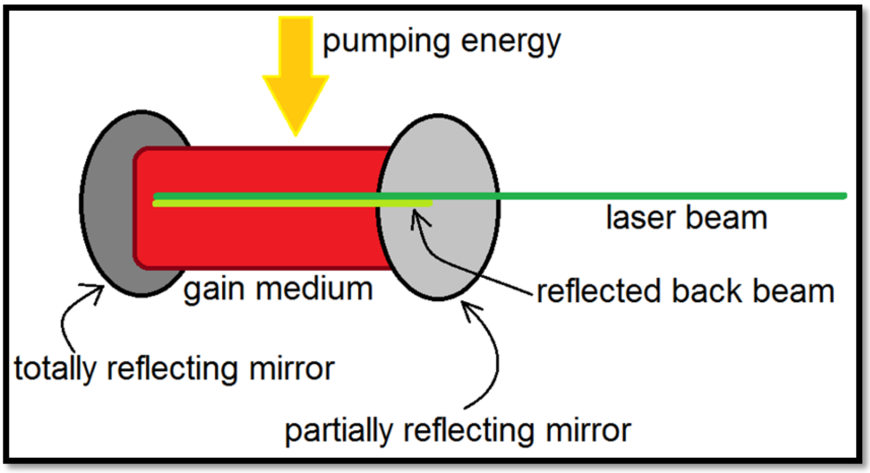

Fig 2: Laser device component

IV. Laser Science

In the 20th century Albert Einstein, described, three possible mechanisms involving proton radiation - absorption, spontaneous emission, and stimulated emission.[17] **"Laser is an acronym for Light Amplification by Stimulated Emission of Radiation"**. Laser utilizes the natural oscillations of atoms or molecules between energy levels for generating coherent electromagnetic radiation usually in the ultraviolet, visible, or infrared regions of the spectrum. It is a device that produces high intensity of a single wavelength and can be focused into a small spot.[13]

LIGHT[18] is a form of electromagnetic energy that behaves as wave and particle. Basic unit of this energy is 'PHOTON'. Normal light are significantly different they emit white light, which is the collection of many colours of the visible spectrum- violet, blue, green, yellow, orange, and red. Whereas, LASER energy is, monochromatic, is of one specific colour. This possesses a property of coherency that is the waves produced are all in phase with one another and have identical shapes when plotted in graph.
The beam is collimated, are in parallel direction with in the laser device. The lens system in the aperture focus the beam into a delivery system and the emitted energy either continue as constant or will diverge at an angle.

The wave of photon travelling defined by two properties-
Firstly, **AMPLITUDE**, the total height of the wave oscillation from top of the peak to zero line on vertical axis (larger the amplitude, greater the amount of work being performed). Secondly, **WAVELENGTH**, distance between any two corresponding point on the wave on the horizontal axis (Fig-3).

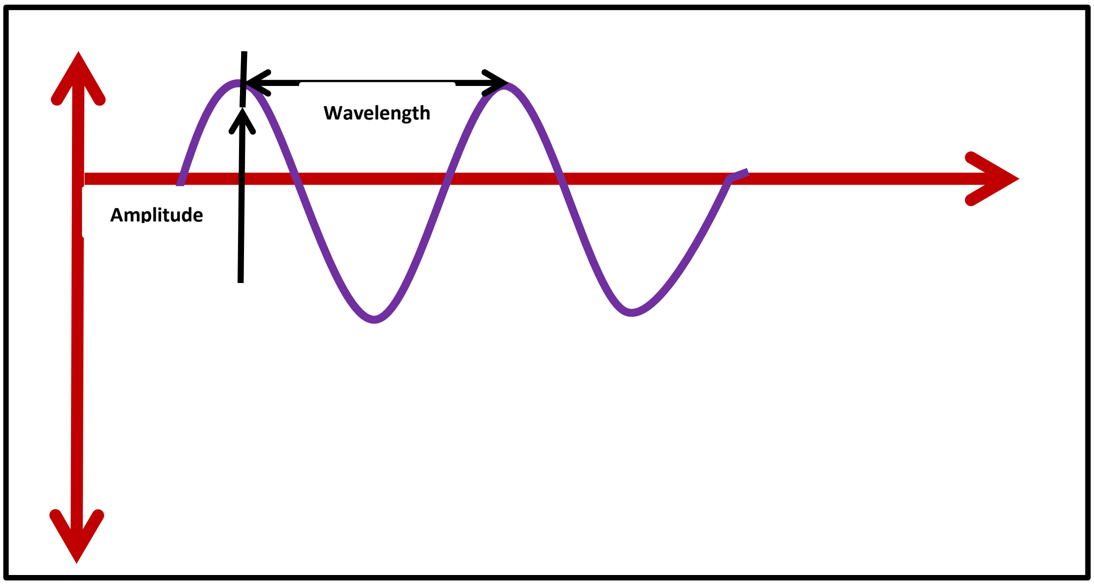

Fig-3. Graph demonstrating amplitude and wavelength.

Stimulated Emission, Max Planck, German physicist, introduced quantum theory in 1900, further, it was notion by Neil Bohr[19], as relating to atomic structure.
Quantum, smallest energy, absorbed by the electrons of an atom a excitation occurs, since natural order prefers substance to be in a resting state, process known as spontaneous emission.
In 1916, Albert einstien[20] theorized that additional photon travelling in the field of excited atom that has the same excitation energy level result in a release of two quanta, or coherent waves of two photons, a phenomenon termed as **'stimulated emission'**.

Amplification, if process continues, more atoms energized, more identical photons get emitted and propagation of this stimulatory wave would result. At a point, the atoms of the active medium are in the elevated rather than the resting state. Constant supply of energy is necessary to maintain this excitation. The photons are reflected back and forth within the active medium to further enhance stimulated emission and successive passes through the active medium increase the power and ultimately collimate the photon beam.

Radiation,[18] laser energy produced in the active model is radiated in a specific form of electromagnetic energy. Wavelengths below (approx. 350 nm) are ionizing radiation, can deeply penetrate biologic tissue, produce charged atoms and molecules, and have a mutagenic effect on cellular DNA. Wavelengths (≥350 nm) cause excitation and heating of the tissue with which they interact. All available dental laser devices are classified as nonionizing because their emission wavelengths exceed 350 nm. (Fig-1)

Lasers are heat producing devices converting electromagnetic energy into thermal energy. Lasers can interact with their target material by either being absorbed, reflected, transmitted or scattered. Absorbed light energy gets converted to heat and can lead to warming, coagulation or excision and incision of the target tissue.[13]

There are two basic emission modes for dental lasers –

- ***Continuous wave***, in which energy is emitted constantly for as long as the laser is activated. Results in increase production of heat.
- ***Pulsed wave***, delivers smaller amounts of energy in an interrupted bursts, there by countering the build-up of heat in the surrounding tissues[13].

Wavelengths can be classified into three categories:

1. The UV range (Ultra-spectrum approx. 400-700 nm).
2. The VIS range (Visible spectrum approx. 400-700 nm).
3. The IR range (Infra-red spectrum approx. 700 nm) to the microwave spectrum.

How laser works?[21]

Atoms in the excited state spontaneously emits photon which bounces back and forth between the two mirrors in the laser tube, they strike other atoms, stimulating more spontaneous emissions. Photons of energy of the same wavelength and frequency escape through the transmissive mirror as the laser beam, which can be focused. As a small intense beam of energy that has the ability to vaporize, coagulate and cut if a lens is placed in front of beam.

V. Characteristics Of Laser

Lasing process occurs when an excited atom is stimulated to emit a photon spontaneously. Spontaneous emission of a photon by an atom stimulates the release of a subsequent photon and so on. This stimulated emission generates a coherent, monochromatic and collimated form of light. When laser light reaches a tissue, it can reflect, scatter, be absorbed or be transmitted to the surrounding tissues (Fig-4). In oral tissue, absorption is due to the presence of free water molecules, pigments, proteins and other macromolecules.[14,22]

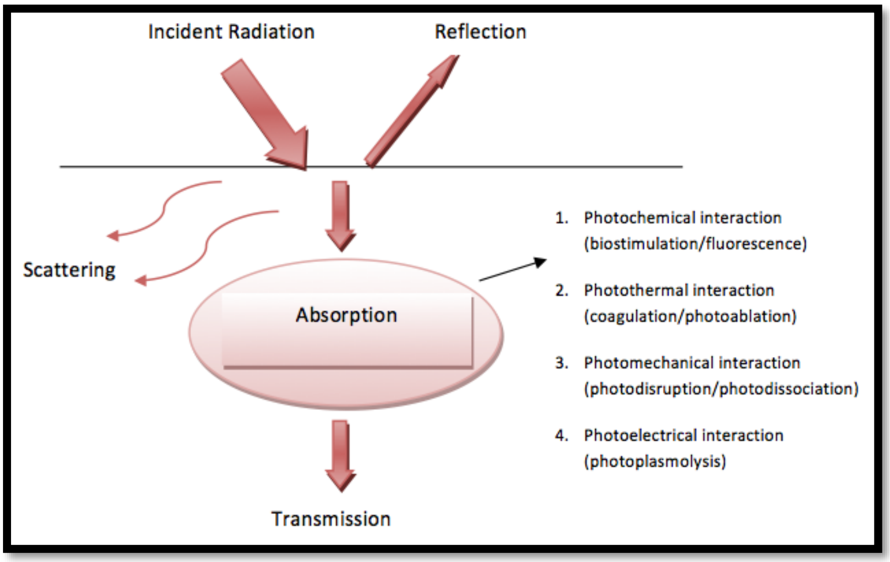

Fig-4: Schematic diagram showing the interaction of laser light in tissue

The photonic absorption within the tissue results in an intracellular or intercellular change. The shorter wavelengths (approx. 500- 1000nm) are readily absorbed in blood elements and chromophores. Argon is highly attenuated by hemoglobin. Diode and Nd:YAG have a high affinity for melanin. The longer wavelengths are more interactive with water and hydroxyapatite. The largest absorption for water is just below 3000 nm (Er:YAG laser). CO_2 laser at 10,600 nm has the greatest affinity for hydroxyapatite and is well absorbed by water.[23]

VI. Thermal Effect On Tissue

Lasers designed for surgery deliver concentrated and controllable energy to tissue. For biological effect of laser on tissues the energy must be absorbed and this will vary as a function of laser wavelength and optical characteristics of the target tissues.[4]

At the surgical site with increasing temperature, the soft and hard tissues are subjected to various tissue changes as mentioned in Table-2.[24]

Table-2: Thermal effect of laser on tissue

TEMPERATURE (°C)	EFFECT
>37	Hyperthermia
>50	Non-sporulating bacteria deactivated
60 to 65	Tissue welding
65- 90	Coagulation
90-100	Protein denaturation
>100	Vaporization and carbonization
>200	Charring and irreversible tissue necrosis

Uses of Lasers

1. Removal of diseased pocket lining epithelium.
2. Antimicrobial effect on micro-biota.
3. Removal of calculus.
4. Root surface detoxification.

Advantages

1. Dry surgical field.
2. Tissue surface sterilization.
3. Less operative time, minimum postoperative pain due to protein coagulum that acts as a biological dressing and seals the ends of sensory nerves.
4. Less mechanical trauma, minimal swelling and scarring observed.
5. Because of low or no heat production, they can be used around dental implants.

6. Reach sites which conventional mechanical instrument cannot.
7. Increased patient acceptance.

Disadvantages

1. The cost of laser is significantly higher.
2. Laser can cause eye damage, so protective glasses are required during its use.
3. There is a burning flesh odour.
4. Combustible gases must be turned off during laser use.
5. Laser plume requires use of a high-filtration face mask, because of the possible presence of pathogens in the plume.
6. Because of the potential hazard of laser light, laser use requires a learning period and strict precautions.
7. Slower healing.

Precautions to be taken[13]

1. Use of glasses for eye protection before treatment, worn by patient, operator, and assistants.
2. Protect the patient's eyes, throat, and oral tissues outside the target site.
3. Use of wet gauze packs to avoid reflection from shiny metal surfaces.
4. Require adequate high speed evacuation to capture the laser plume.

Risks while treatment[13]

1. By direct ablation excessive tissue destruction can be seen and thermal side effects.
2. Excessive ablation of root surface and gingival tissue within periodontal pockets.
3. Thermal injury to the hard and soft tissue architecture.

VII. Application Of Laser In Dentistry

1. On Soft tissue

The types of lasers used for periodontal applications are the diode, CO_2, Nd:YAG and Erbium: Yttrium-Aluminium-Garnet (Er:YAG). All lasers except CO_2 laser transmit the energy through an optical fiber, with the use of a handpiece and contact to provide tactile feedback. The CO_2 laser uses a light beam directly to guide the operator.[25]

Non-Surgical Periodontal Therapy

The use of lasers as an adjunct to conventional mechanical therapy is based on the claim that eradication of pathogenic bacteria will produce a sterile field, leading to elimination of periodontal pockets.[25]

Surgical Periodontal Therapy

Lasers have been used for a number of types of soft tissue surgeries, including gingivoplasty, gingivectomy, frenectomy,[26] vestibular deepening, operculectomy, gingival troughing, removal of mucocutaneous lesions, soft tissue biopsies and gingival sculpting techniques associated with implant therapy and flap surgeries. Lasers can also be used for clinical crown lengthening for esthetic and prosthetic reasons without gingival flap reflection.[4,25] (Table-3)

Table-3: Current and potential soft tissue applications of lasers in dentistry[14]

LASER TYPE		**POTENTIAL SOFT TISSUE APPLICATION**
Gas Laser	Argon (Ar)	Intraoral soft tissue surgery, Sulcular debridement (subgingival curettage in periodontitis and peri-implantitis).
	Helium Neon (HeNe)	Analgesia, Aphthous ulcer treatment.
	Carbon Dioxide (CO_2)	Analgesia, Intraoral and implant soft tissue surgery, Aphthous ulcer treatment, Removal of gingival melanin pigmentation and mucosal lesion.

Diode Lasers	Galium Aluminum Arsenide (GaAlAs) Galium Arsenide (GaAs)	Analgesia, Intraoral general and implant soft tissue surgery, Sulcular debridement (subgingival curettage in periodontitis and peri-implantitis) Aphthous ulcer treatment, Removal of gingival melanin pigmentation.
Solid State Lasers	Neodymium:YAG (Nd:YAG) Erbium:YAG (Er:YAG), Erbium:YSGG (Er:YSGG), Erbium,chromium:YSGG (Er,Cr:YSGG)	Analgesia, gingival troughing, esthetic contouring of gingiva, treatment of oral ulcers, Sulcular debridement (subgingival curettage in periodontitis), Removal of gingival melanin pigmentation. Analgesia, Intraoral general and implant soft tissue surgery, Sulcular debridement (subgingival curettage in periodontitis and peri-implantitis), Aphthous ulcer treatment, Removal of gingivalmelanin/metal-tattoo pigmentation

2. On hard tissue

Dental lasers can be used to cut, incise, and ablate hard and soft tissues.[24] Erbium lasers are unique in that they are the only lasers that can cut both hard and soft tissues.[27] Hard tissue ablation results from micro evaporative expansive events that occur within the target due to an extremely rapid buildup of heat and spontaneous evaporation of the available water content. This process also is referred to as a ***thermo mechanical effect*** due to the pressure build up involved.[28] Hard tissues lasers are used to remove used to remove a defective composite restoration, eradicate recurrent decay found underneath, and perform any soft/ hard tissue crown lengthening.[24]

Table-4: Current and potential hard tissue applications of lasers in dentistry.

HARD TISSUE APPLICATION	LASER TYPE
1. Caries and calculus detection	Indium Gallium Arsenide Phosphorus (InGaAsP)
2. Hard tissue ablation, dental caries and calculus removal	Excimer lasers, Frequency-doubled Alexandrite, Er:YAG, Er,Cr:YSGG,
3. Treatment of dentin hypersensitivity	Nd:YAG, Er:YAG, Er,Cr:YSGG, CO_2, KTP and diode lasers
4. Laser analgesia	HeNe, CO_2, Nd:YAG, Er:YAG and Er,Cr:YSGG lasers
5. Root canal disinfection	Galium Aluminum Arsenide (GaAlAs) and Galium Arsenide (GaAs), Neodymium:YAG (Nd:YAG), Erbium:YAG (Er:YAG), Erbium:YSGG (Er:YSGG), Erbium, chromium:YSGG (Er,Cr:YSGG)
6. Bleaching/tooth whitening	Argon (Ar)
7. Root biomodification	Defocussed CO_2, Nd:YAG, Erbium:YAG (Er:YAG)
8. Osseous surgery	Erbium:YAG (Er:YAG), Erbium:YSGG (Er:YSGG), Erbium,chromium:YSGG (Er,Cr:YSGG)

VIII. Conclusion

In dentistry Lasers and their use is relatively new, it serve as an adjunctive or alternative to conventional mechanical periodontal and peri-implant treatment. Soft tissue surgery is one of the major indications of lasers. Nd:YAG, CO_2, diode, Er:YAG and Er,Cr:YAG lasers are generally accepted as useful tools for these procedures. Currently, Er:YAG and Er,Cr:YSGG laser possess characteristics suitable for dental treatment, due to its durability to ablate soft and hard tissues with minimal damage. Considering the numerous advantages of laser, its use with conventional treatment or alone has the potential to improve the condition of the periodontal pockets. Thus, laser systems, with the ablation effect of light energy different from conventional mechanical debridement, may emerge as a new technical modality for periodontal therapy in the near future. A laser has proved to be a blessing in disguise if used safely and properly.

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