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Lasers : A Lightening Bolt Of Zeus In Periodontology

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Abstract

Background. Dentistry has revolutionized over the past decade to the benefit of both the clinician and the patient. One technology that has become increasingly utilized in clinical research is that of the LASERS. The word laser stands for Light Amplification by Stimulated Emission of Radiation. A laser is a device that transforms light of various frequencies into a chromatic radiation in the visible, infrared and ultraviolet regions with all the waves in phase capable of mobilizing immense heat and power when focused at close range.

Relevance for patients. Various lasers has been tried and being used in periodontology ranging from soft tissue lasers like Diode laser to hard tissue lasers like Nd:YAG, Er:YAG, CO_2 laser showing promising future with versatile role in their application and favorable outcomes. This review article aims to give an insight on the different lasers used and their diverse applications in the field of periodontology.

Keywords: LASER, Diode laser, Nd:YAG, Er:YAG, CO2 laser

Introduction

LASER stands for **Light Amplification by Stimulated Emission of Radiation**. Lasers span from those activated by natural gases, elements, molecules, or man-made crystals to those that measure distances to the moon, create laser guided warfare, and record the price of our groceries. Over the past few decades, lasers have emerged strongly in dentistry especially in the field of periodontology.

The concept of lasers dates back to **1917** with theory given by **Einstein, theory of stimulated emission**, 1960 it came in light when ***Theodore Maiman*** [1] created the first working laser. Use of Lasers are in a wide array of cosmetic procedures and medical procedure like surgeries like cataract surgery [2] removal of hair.[3] However, it gained popularity only recently in clinical dentistry. Lasers are popular for their ability to ablate hard tissues with minimum anesthesia, [4 ,5] reduces count of bacteria in root canals [6,7] and even provide hemostasis of soft tissues during their use. [8,9] They are also used for cavity preparation, caries detection [5] tooth whitening, [10] gingival incisions, de-epithelization [11] etc. In periodontology, use of lasers is due to the potential in promoting periodontal attachment, reducing or to some extent elimination of the bacterial load/count in the management of periodontal pockets, treatment of hyperpigmentation, LANAP, Photodynamic therapy, biomodulation, management of gingival overgrowth, crown lengthening procedures, [6] debridement of root surfaces, calculus removal [12] and latest use being in treatment of dentinal hypersensitivity and management of peri implant mucositis and peri implantitis. [13]

History Of Laser

Table 1: History of lasers

SNO	YEAR	EVENT
1.	1916	Theory of light emission. Concept of stimulated emission - **Albert Einstein**
2.	1951	The inventor of the MASER (Microwave Amplification of Stimulated Emission of Radiation) at Columbia University - First device based on stimulated emission, awarded Nobel prize 1964 - **Charles H Townes**
3.	1957	First document defining a LASER; notarized by a candy store owner. Credited with patent rights in the 1970s - **Gordon Gould**
4.	1960	LASER patent No. 2,929,922 - **Arthur L Schawlow Charles H Townes**
5.	1960	Invented first working LASER based on Ruby. May 16th 1960, Hughes Research Laboratories **- Theodore Maiman**
6.	1961	Invented Helium Neon (HeNe) LASER at Bell Labs - Ali Javan , William Bennet , Donald Herriot
7.	1964	Inventor of first working Nd:YAG LASER at Bell Labs - J E Geusic, H M Markos , L G Van Uiteit, Bob Thomas
8.	1964	Inventor of CO2 LASER at Bell Labs - Kumar N Patel
9.	1964	Invention of Argon Ion LASER at Hughes Labs - William Bridges
10.	1970	First Excimer LASER at Lebedev Labs, Moscow based on Xenon (Xe) only - Nikolai Basov's Group
11.	1974	First rare gas halide excimer LASER at Avco Everet Labs - J J Ewing and Charles Brau
12.	1981	Awarded Nobel Physics Prize for work in nonlinear optics and spectroscopy. Arthur Schawlow Nicolas, Bloembergen
13.	1985	First commercial LASER eye surgery device and method, US patent No. 4,525,942 and UK patent No. GB 2 157 483 A at Kigre, Inc. John D. Myers

Basic Laser Science

Light

Light which behave as both wave as well as particle is a type of electromagnetic energy. The basic unit of light is called a 'photon'. [14] Ordinary light is a white diffuse glow, although it is the sum of many colours of the **visible spectrum (VIBGYOR)**. Laser light has one specific colour, which may be visible or invisible. This property is termed '**Monochromacity**'.

Wave of the photon which are produced by the laser can be defined in three measurements. They are:-

Velocity - the speed of light

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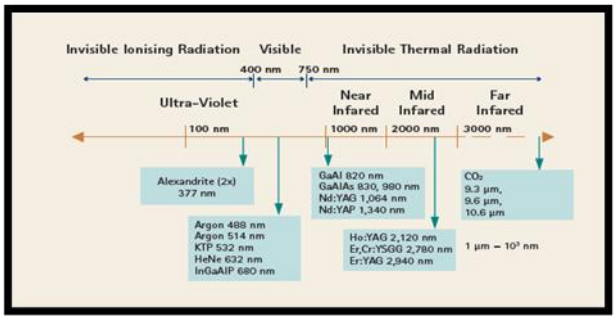
Amplitude - the total height of the wave oscillation from top of the peak to the bottom on a vertical axis

Wavelength - the distance between any two corresponding points on the wave on the horizontal axis.

Thus, correlation can be made as when the amplitude is larger, amount of work performed will be greater. Measurement of lasers is done in microns (10-6m) or nanometers (10-9m) as shown in Fig 1

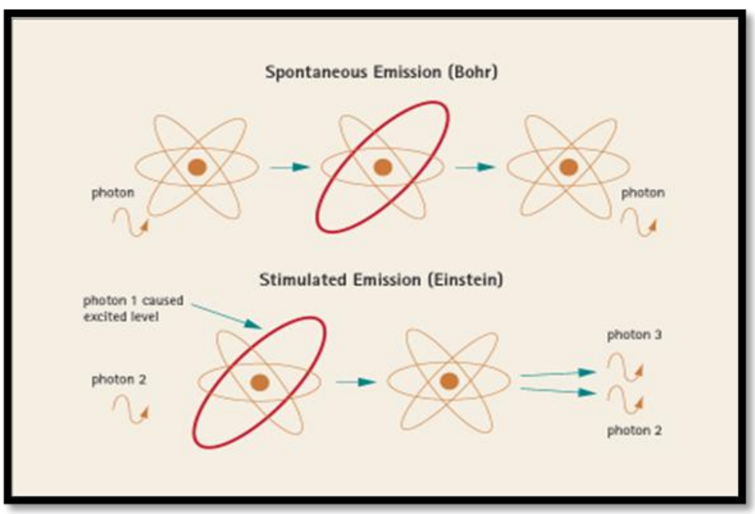
Fig 1 - Wavelengths of dental laser and the Electromagnetic spectrum [15]



Stimulated emission

Stimulated emission (Fig 2) which is based on quantum theory of physics. The smallest unit of energy is known as 'quantum'. Excitation of the atom or molecule is seen when electron absorbs this quantum. Release of this quantum is known as 'spontaneous emission'. [16,17]

Fig 2 - Photonic emission, showing spontaneous (Bohr's model, upper) and stimulated emission (Einstein's model, lower)



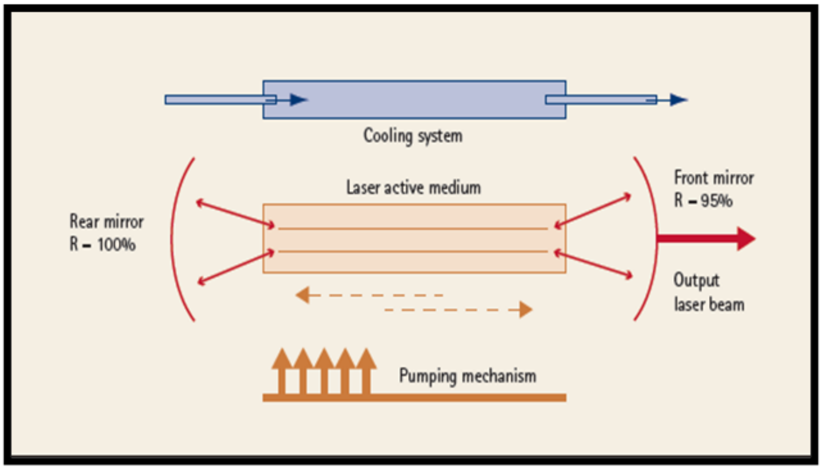
Properties Of Lasers

Laser light is a monochromatic light in visible or invisible range with three primary characteristics. [18]

1. Collimation (parallel rays)
2. Coherency (synchronous waves)
3. Efficiency.

Components Of Laser [8,19]

Fig 3 - Basic components of lasers



The basic components of lasers include (as shown in Fig 3) :

Optical cavity

1. Lasing medium/gain medium/Laser active medium placed within the optical cavity
2. Parallel mirrors

Pump energy source / Pumping mechanism

Optical Resonator

Cooling system

Control panel

Delivery system

Delivery System

Beam of laser can be delivered, in two different emission modes

Continuous wave:

Continuous emission of beam of single or one power level with foot control. E.g. Diode, CO_2 lasers

Pulse mode:

1. Gated pulse mode – super pulse mode
2. Free running pulse mode or true pulsed

Laser Delivery Tips (As Shown In Table 2)

Laser Type	Delivery Tip
Carbon dioxide	Hollow waveguide; beam focused when 1 to 2 mm from target surface.
Neodymium: yttrium aluminum-garnet	Flexible fiber optic system of varying diameters; surface contact required for most procedures.
Holmium: yttrium aluminum-garnet	Flexible fiber optic system; surface contact required for most procedures.
Erbium:yttrium aluminum-garnet	Flexible fiber optic system or hollow waveguide; surface contact required for most procedures.
Erbium, chromium:yttriumselenium galliumgarnet	Sapphire crystal inserts of varying diameters; surface contact required for most procedures.
Neodymium: yttrium aluminum-perovskite	Flexible fiber optic system; surface contact required for most procedures.
Indium-galliumarsenide-phosphide;gallium aluminum arsenide;galliumarsenide	Flexible fiber optic system; surface contact required for most procedures.
Argon	Flexible fiber optic system.

Target Tissue
Effects In

Relation To Temperature

1. At 37 to 50 degree – hyperthermia
2. At 60 to 70 degree – Coagulation, protein denaturation
3. At 70 – 80 degree – Welding
4. At 100 – 150 degree - Ablation and Vaporization
5. More than 200 degree - Carbonization

Laser – Tissue Interaction

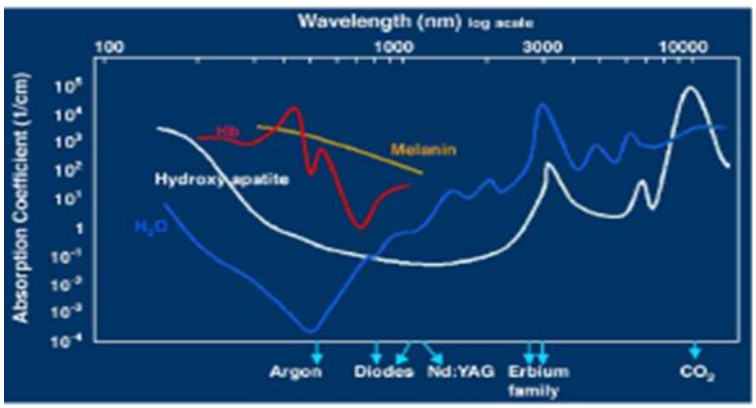
The impact of laser emission on biologic structures is similar to the effect of radiant light energy when reacts with matter. There are various criteria and factors which determine the effect of this interaction like the power density of the beam, the wavelength of radiant energy emitted by the laser and the temporal characteristics of the beam energy such as continuous vs pulsed delivery, pulse rate and pulse duration. These factors are inherent to the particular type of lasers. Other variables that relate to differences in the method of energy transfer are deliver systems such as contact vs noncontact optical fiber delivery and focused vs unfocused beam. The biologic factors that influence laser tissue interactions are the optical properties of various tissue elements that govern how specific molecular and chemical components in tissue react with light energy. According to Dederich et al 1991, nature and extent of the tissue response is determined by optical properties of tissue elements namely absorption, transmission, reflection and scattering of the laser beam. [20]

Absorption - It is a property which is inverse of transmission. This interaction is considered to be the most beneficial property of laser. Every laser has different wavelength and in turn interacts differently with the tissues thus have unique effect. This uniqueness is due to Specific Absorption by the chromophores of the specific energy (light) as shown in Fig 4.

Chromophores which are commonly encounters in laser interactions in dentistry are mainly melanin, hydroxyapatite, haemoglobin and allied pigmented proteins and water.

Red colour to the atrial blood is imparted by the haemoglobin which is present as it reflects the red wavelength. Hence it is understood that it absorbed green and blue wavelengths. Similarly Venous blood which contains less haemoglobin will appear darker as it absorbs red wavelength also. Colour to the skin is imparted by molecule called melanin which is responsible for absorbing shorter wavelengths. In general, the shorter wavelengths (from about 500–1000 nm) are readily absorbed in pigmented tissue and blood elements. Haemoglobin absorbs argon and has less interaction with Diode and Nd:YAG whereas melanin absorbs Diode and Nd:YAG. Water and hydroxyapatite interact more with higher wavelengths. Hydroxyapatite is seen to absorb Erbium well. Water is seen to absorb CO_2 at 10,600 nm and high affinity of CO2 laser is seen towards the tooth structure.

Fig 4 - Absorption coefficients of haemoglobin, melanin, hydroxyapatite and water (in 1/cm) relative to laser wavelength (in nm)



Benefits Of Laser-Tissue Interaction

Table 3: Benefits of laser tissues interaction in treatment of soft and hard tissue

SOFT TISSUE	• Incision, Coagulation, ablation, vaporization of the tissue • Dry field during surgery • Reduction in post of oedema • Antimicrobial property • Reduced scarring
HARD TISSUE	• Selective and faster ablation • Minimally invasive during cavity preparation • Reduced thermal effects on pulp • Sterilization of the cavity

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Laser In Periodontal Therapy

The history of laser therapy as applied to periodontics began in the early 1960's with the development of the argon, carbon dioxide and Nd: YAG laser. In ***1965, Kinersly et al*** [21] stated the potential of ruby laser in removing dental calculus. However clinical problems might present while they use limiting vaporization selectively to calculus without damaging the underlying tooth. Both soft and hard tissues are always targeted while using lasers for the treatment of periodontal lesions. Adequate hemostatic effect and excellent ablation of soft tissue can be achieved while using the more common high power laser like Nd: YAG and CO_2. By 1990's the application of laser systems in the field of periodontal therapy was limited to soft tissue procedure like frenectomy and gingivectomy but their application in periodontal hard tissue had previously proved to be unpromising clinically.

In the early and mid 1990's the clinical research began on the use of Nd: YAG laser on root surface debridement and pocket curettage. Meanwhile ***Hibst et al 1988 and Keller et al 1989*** [22] showed the feasibility of the use of dental hard tissue ablation by Er: YAG laser irradiation which is highly absorbed by water. Later in mid 1990's ***Aoki et al and Keller et al*** [23] demonstrated the use of Er:YAG laser in periodontal hard tissue procedure such as decontamination of diseased root surface and dental calculus removal. Er:YAG laser application in surgeries of bone has also been studied in vitro and in vivo.

However, clinical problems might occur while limiting the vaporization selectively to calculus without harming the underlying tooth. Since the periodontium is consists of gingiva, periodontal ligament, cementum, and alveolar bone, it is inevitable that one of the tissue i.e. hard or soft is spared and hence both get targeted simultaneously while using lasers in the treatment of periodontal lesions. The frequently used high power lasers such as CO_2 and Nd:YAG are capable of getting excellent soft tissue ablation, and have an adequate haemostatic effect. [24,25,26,27,28]

Invention of this laser brought the spectrum of hard tissue treatment in periodontology. The diode lasers as well as Nd:YAG lasers are now a days used for curettage of pocket lining by clinicians because of their advantage of being flexible fiber delivery system, which is appropriate for their insertion in pocket. However, till now, there is a shortfall of basic and clinical research giving scientific support for these procedures. In the field of dentistry, CO_2, Nd:YAG, Er: YAG, diodes, Argon, Er,Cr:YSGG, alexandrite and excimer lasers are under research in vitro or are in clinical use. [29,30,31,32,33,34]

APPLICATION OF LASERS IN PERIODONTOLOGY (As Shown In Table 4) [35,36,37]

1. NSPT
    - **Elimination of the Calculus** deposits and root-surface detoxification.
    - **Bactericidal effect** on the microorganisms present in the periodontal pocket
    - **Elimination of the Pocket lining** epithelium
2. GINGIVAL CURRETTAGE
3. DENTINAL HYPERSENSITIVITY
4. SURGICAL PERIODONTAL THERAPY
5. CLINICAL CROWN LENGTHENING
6. GINGIVECTOMY AND FRENECTOMY
7. REGENERATIVE PERIODONTAL SURGERY
8. GINGIVAL HYPER PIGMENTATION

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9. IMPLANTS

10. TREATMENT OF PERI IMPLANTITIS

Table 4: Wavelength, delivery system and clinical application of various laser in periodontology

Laser type	Wave-length (in nm)	Wave form	Delivery System	Clinical application in periodontics
Carbon-di-oxide (CO_2) [38,40]	10600	Continuous mode and Gated mode	Hollow waveguide /Articulated arm	• Ablation of Soft tissue • Treatment of ulcers like apthous ulcer • Dentinal hypersensitivity treatment • Analgesia • Melanin depigmentation
Neodymium:Yttrium aluminium –garnet (Nd:YAG) laser [40,41,42,43]	1064	Pulsed mode	Fiberoptic system (Flexible)	• Ablation of Soft tissue and incisions • Debridement of the Sulcus • Antimicrobial agent • Subgingival curettage • Melanin depigmentation
Erbium: yttrium-aluminium-garnet Er:YAG laser [38,44]	2940	Free running pulsed mode	Flexible fiberoptic system or hollow waveguide	• Ablation of Soft tissue and incisions • SRP • Subgingival curettage • Osteoplasty and ostectomy Decontamination & Degranulation of the implants

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				• Analgesia • Dentinal hypersensitivity treatment • Melanin depigmentation
Erbium ,chromium:yttrium-selenium-garnet (Er,Cr;YSGG) [35]	2780	Free running pulsed mode	Air-cooled fiberoptic/ handpiece	• Ablation of Soft tissue and incisions • Subgingival curettage • SRP • Osteoplasty and ostectomy
Argon (Ar) laser [45]	488 and 514	Continuous mode and Gated mode	Fiberoptic system (Flexible)	• Ablation of Soft tissue and incisions • Used for sulcular debridement of peri-implant tissues and periodontium
Diode Laser – • Indium-gallium-arsenide-phosphide • Gallium-aluminium-arsenide;Gallium • InGaAsP, GaAlAs • GaAs [39,40,47,48,49]	635to 980	Continuous mode and Gated mode	Fiberoptic system (Flexible)	• Ablation of Soft tissue and incisions • Melanin depigmentation • Use as Antimicrobial agent • Sulcular debridement • Dentinal hypersensitivity treatment • Subgingival curettage • Analgesia

Helium-neon (He-N) [46]	632	Continuous mode and Gated mode	Fiberoptic system (Flexible)	• Soft tissue surgery • Implant soft tissue surgery • Sulcular debridement, • Treatment of dentin hypersensitivity • Analgesia • Apthous ulcer treatment

Recent Advances In Laser Therapy

1. LOW-LEVEL LASER THERAPY (LLLT)
2. WATERLASE
3. LASER-ASSISTED NEW ATTACHMENT PROCEDURE [LANAP]
4. LASER INSTRUMENT FOR MEASURING TOOTH MOVEMENTS
5. PHOTODYNAMIC THERAPY
6. DIAGNODENT
7. LASER WELDING
8. PERIOWAVE

Associated Risk And Precautions With Use Of Lasers Clinically

Precaution Pre And Post Irradiation Procedure

1. Safety Glasses must be used for eye protection of the operator, assistance and patient
2. Protection should also be provided to eyes, throat and oral tissues outside the target sights of the patients while irradiation
3. Prevent inadequate irradiation
4. Ensure that there is high volume suctions to capture the laser plume to capture the
5. To avoid refection from the shiny metal surface, use of wet gauge is advocated

Potential Risks

1. Damage at the bottom to the attachment apparatus of the pocket
2. Excessive destruction of the tissue by direct ablation
3. Side effects due to heat generation (Thermal)
4. Excessive ablation within the periodontal pockets of the root surface & gingival tissue
5. Thermal injury to the pulp, gingival tissue, bone and root surface

Discussion

Stern, Sognnaes and Goldman *et al*., in 1964 were the pioneers of the application of a laser to dental tissue describing the effects of ruby laser on enamel and dentine. [36] The principle effect of laser energy is photothermal; this effect on tissue depends on the degree of temperature rise and corresponding reaction of the interstitial and intracellular water. [50]

Clinical lasers are of two types: "soft" and "hard" lasers. Soft lasers are claimed to aid healing and to reduce inflammation and pain. However, few rigorous studies are available to support their use. Surgical hard lasers can cut both hard and soft tissues, and newer varieties can transmit their energy via flexible fiberoptic cables. Many procedures can be performed without local analgesia, and because lasers sterilize as they cut. [51] In hard tissue application, the laser is used for caries prevention, bleaching, restorative removal and curing, cavity preparation, dentinal hypersensitivity, growth modulation and for diagnostic purposes, whereas soft tissue application includes wound healing, removal of hyperplastic tissue to uncovering of impacted or partially erupted tooth, photodynamic therapy for malignancies, photostimulation of herpetic lesion.

Use of the laser proved to be an effective tool to increase efficiency, specificity, ease, and cost and comfort of the dental treatment. [52,53]

Conclusion

Potential of lasers as a treatment modality is impressive and its range of clinical application is very wide. Laser's use in the field of periodontology had been for various purposes.

The main advantages of laser are that there will be very minimal bleeding, sterilization of the wound, 90% less pain, very minimal edema, better healing, no suture required etc. The main disadvantage being the cost factor and 'smoke' which is emitted called laser plume.

The laser safety has to be maintained during the surgery. The safety glasses has to be worn by the operator and patients eyes should be covered by wet gauge and no metallic instrument should be used as the laser light might reflect and injure the other tissues.

Laser therapy in dentistry and dental surgery is a potent but emerging science. Soft tissue applications are well-documented and gaining acceptance. The laser thus opens a very promising path for investigation that may ultimately lead not only to further control gingivitis but also revolutionary changes in clinical periodontics.

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