Lasers & its Contemporary Practice in Periodontics: A Narrative Review

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Abstract: ***This narrative review presents an update on the basics and practical application of Laser in periodontics.***

Keywords: Lasers, Light, Biostimulation, Low-Level Laser, Periodontics

1. Introduction

Light amplified by stimulated emission of radiation is abbreviated as **LASER**. It is a device that emits a concentrated beam of light with diverse beneficial effects. Lasers are frequently used in medical and dental therapy. In dentistry, lasers are indicated for incisions, coagulation of blood vessels, sterilization, and desensitization of nerve vessels.

The first ruby laser was invented by Maiman in 1960. Later, different pioneers modified it, to develop the hard & soft tissue lasers we use today.

Although lasers have been used routinely in dental therapy in clinics and hospitals, there is still controversy on the actual benefits of lasers. Systematic studies and metanalysis have shown that lasers have no statistical significance compared to surgery with a scalpel or conventional therapy. Further, the exorbitant cost of lasers and the risks associated weigh down the interests. Still, the painless, bloodless, and fancy of lasers makes it an appealing option for patients to choose from.

This narrative review article discusses the important dental lasers, the types commonly used in dentistry and, the benefits and controversies surrounding them.

Historical Background: A timeline of important events in the history of Lasers is outlined in figure 1. [1-8]

Terms & Nomenclature:

L is Light: Monochromatic, Coherent, and Collimated

Monochromatic: The laser light has one single wavelength (Single color). The amount of energy released when an electron drops from outer to inner orbit determines the wavelength of light. (Figure 1.3)

Coherent: all the photon has uniform wavelength and frequency.

Collimated / Directional: All the emitted light waves are monophasic, parallel to each other and the beam divergence is low. For fair efficacy, it should be concentrated and focused. (Figure 1.4)

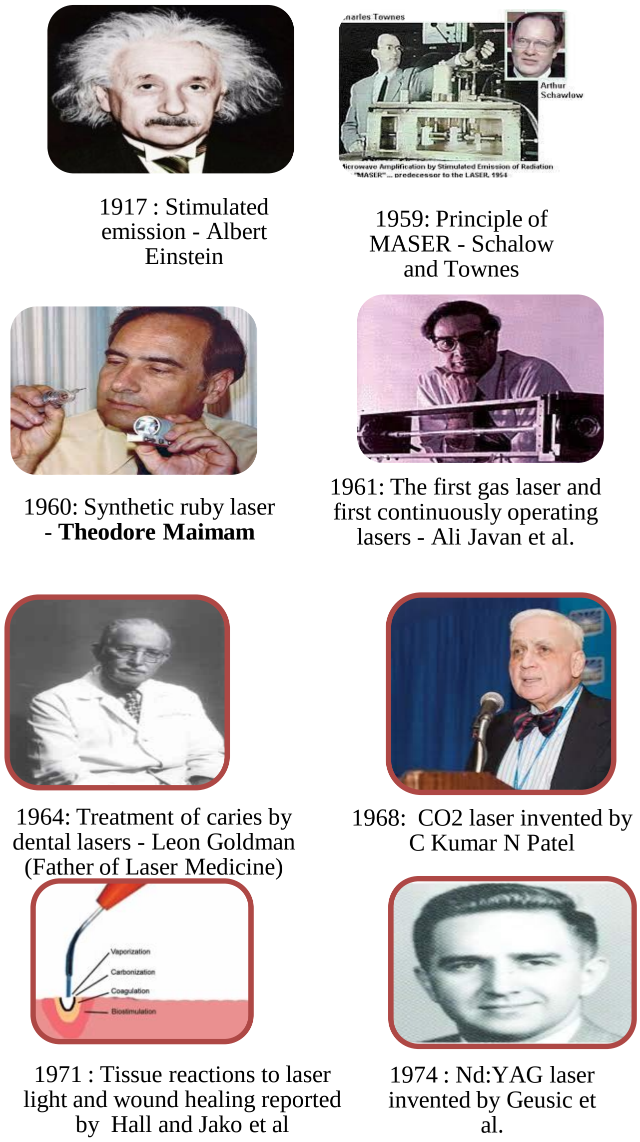


Figure 1.1: Timeline of Laser history

A is Amplification: Amplification can be defined as an intense beam of light directed at a spot. When electrons make the transition from one energy level/state to another, atoms absorb or emit a photon. When an atom relaxes, it emits photons leading to stimulation of the Laser.

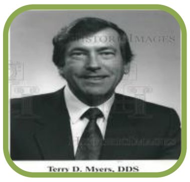
E is Emission: Einstein in 1917 postulated the concept of stimulated emission. As per it, when an atom goes excited to the relaxed state, a photon is released (in form of light/energy). (Figure 1.5 -1.8)

1977 : Ar laser was invented by Kiefhaber

1977 - Shafir recorded the first case in OMFS using dental lasers

1988 : Er:YAG laser was invented by Hibst and Paghdiwala

1989 : Nd:YAG laser used in soft tissue surgery was invented by Midda et al.



1989 : Terr Myers & Myers - got FDA approval for use of laser in dentistry (Nd: YAG Laser)

1990 : First opthalmic use of Ruby laser

1995 : Dental use of Laser started

Figure 1.1: Timeline of Laser history

R in Radiation: refers to the wavelength & frequency of the photon emitted by an object. Usually, a wavelength between 532 nm (visible spectra) to 10604 nm (CO_2) is used in Laser.

Table 1: Classification of lasers

1.	Based on active media	a) Solid State : Nd: YAG Laser b) Gas: He & He Ne laser c) Semiconductors: GaAs laser d) Excimer: Argon laser
2.	Based on action	a. Contact mode (focused or defocused) - Ho:YAG ; Nd: YAG b. Non-contact mode (focused or defocused) - CO_2
3.	Based on application	a) Soft tissue laser - Argon, Co_2, Diode; Nd: YAG. b) Hard tissue laser - Er: YAG c) Resin curing laser / Nonsurgical Laser devices - Argon
4.	Based on the level of energy emission	a. Soft lasers (UV & visible): He-Ne; Ga-Arsenide. b. Hard lasers (High energy level, Infrared): Er: YAG laser; CO_2 laser.
5.	Based on the potential hazard	Figure 1.2
6.	Based on mode of operation	a. CW b. Pulsed

Figure 2: Classification of Laser

Laser class	Hazard or potential for injury	Typical ouptput power P (continuous wave laser)	Typical use
1	Safe under reasonably foreseeable conditions	P <0.4 mW	Scanner checkouts, DVD players
1M	Hazardous to the eye when using telescopic optical instruments (otherwise as in class 1)	P <0.4 mW; but the beam diameter is greater than 7 mm	
2	Direct intrabeam viewing must be avoided—retinal injury is possible at intra-beam viewing times exceeding 0.25 s	P <1 mW	Laser pointers, laser spirit levels
2M	Hazardous to the eye when using telescopic optical instruments (otherwise as in class 2)	P <1 mW; but the beam diameter is greater than 7 mm	
3A	Hazardous to the eye only when using telescopic optical instruments	P <5 mW; but the beam diameter is greater than 7 mm and the power density is related to the same pupil diameter as in class 2 lasers	
3R	Hazardous to the eye	P <5 mW	Show and projection lasers, material pro-cessing lasers
3B	Always hazardous to the eye	P <500 mW	
4	Always hazardous to the eye and skin	P >500 mW	

Figure 1.2: Classification of Laser based on the potential hazard

Component of LASER: A simple diode laser has three important components: the Laser medium, optical cavity/ Laser tube, and an external power source. An illustration of the same is given in figure 2.

1) A media: Can be Solid (Certain laser crystals and glasses such as Nd: YAG, Yb: YAG, Yb: glass, Er: YAG), Liquid (dye lasers), or Gas (CO2 lasers and excimer lasers).
2) A laser tube: it’s an optical cavity with two mirrors at two ends. One is fully reflective while the other is partially transmissive.
3) An external power source will excite the atoms to higher energy levels.

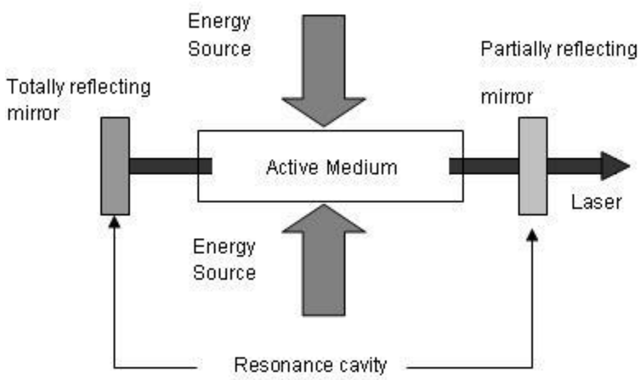


Figure 2: Parts of dental Laser

Laser delivery system: aids in precision positioning and delivery of laser at the desired site.

a) Articulated arms (with mirrors at joints)-for UV, visible, and infrared lasers.

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b) Hollow waveguides (flexible tube with reflecting internal surfaces)-for middle and far-infrared lasers.
c) Fiber optics-for visible and near-infrared lasers.

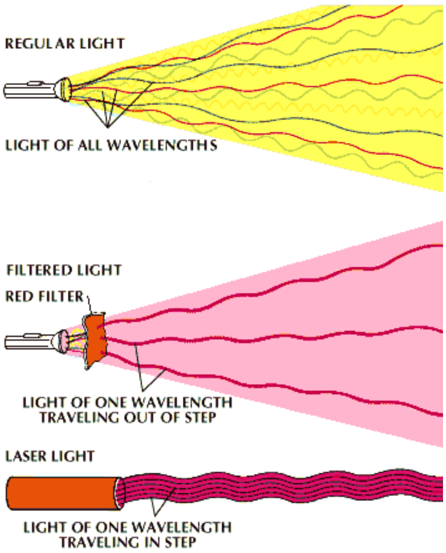


Figure 1.3: Monochromatic wavelength and frequency

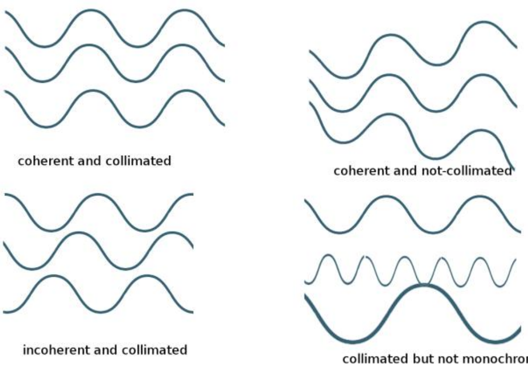


Figure 1.4: Collimated laser beam

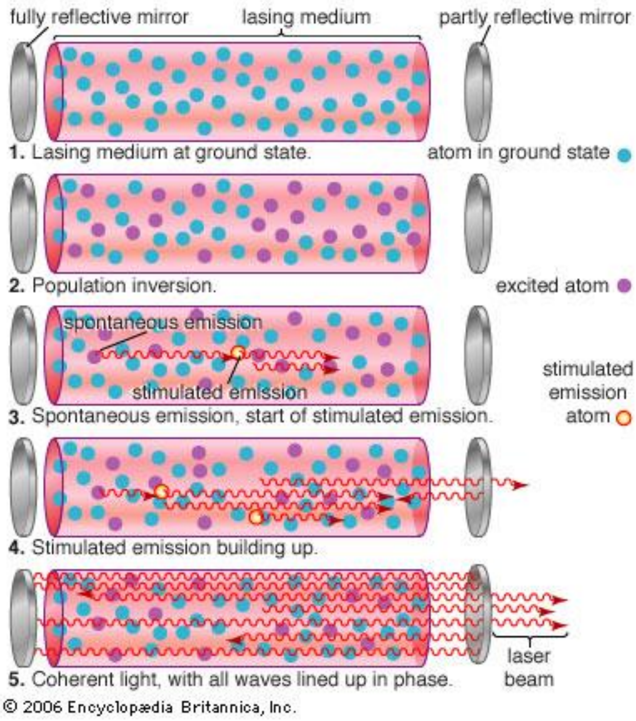
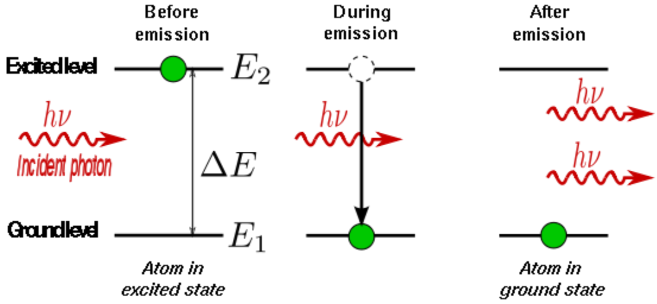


Figure 1.5: Emission of Laser beam



$$E_2 - E_1 = \Delta E = h\nu$$

Figure 1.6: Stimulated emission

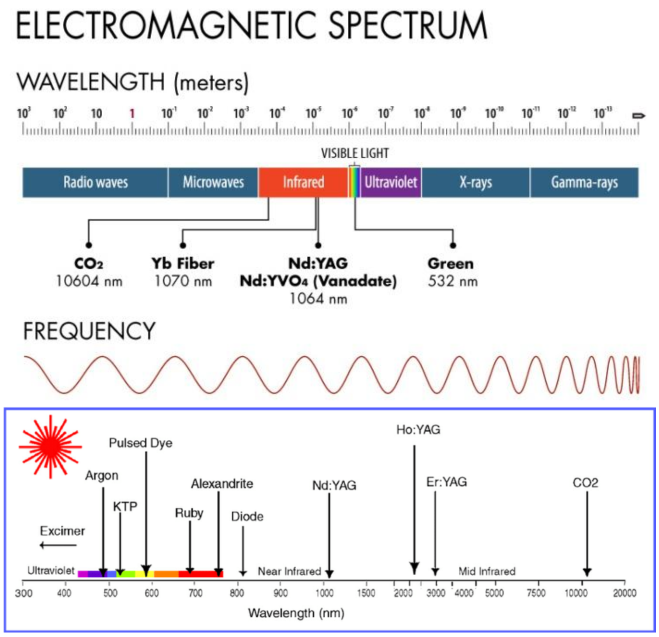


Figure 1.7: Electromagnetic spectrum

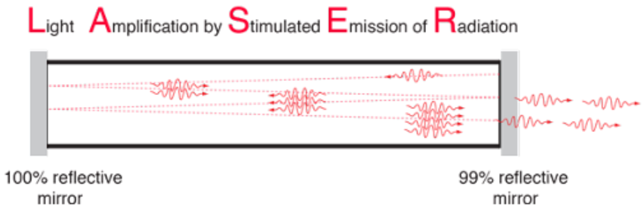


Figure 1.8: Laser beam

Classification of Lasers: A briefly updated classification of Laser is given in Table 1. [9-16]

Laser emission modes:

a) Continuous pulse mode: means the laser switch is turned on the entire time.
b) Gated pulse mode: has periodic on & off phases.
c) Free running pulse mode: it is Computer controlled. In this mode, an extremely high-energy laser beam is emitted for a short duration (10-12 picoseconds or 10-15 Femi seconds) followed by a relatively longer duration of the gap.

Laser tissue interactions:

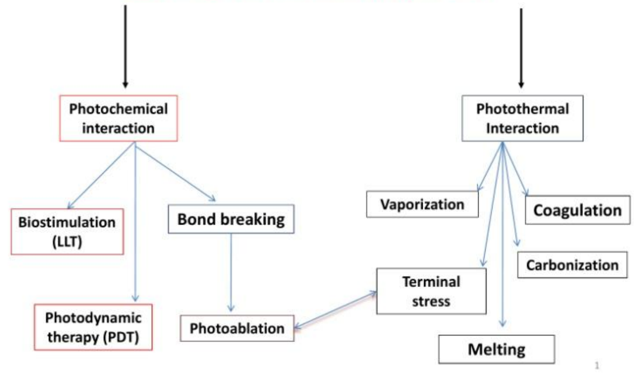
- When the laser beam is directed at human skin, two things happen: most of it is absorbed (interact with soft and hard tissue) and rest is scattered or reflected.

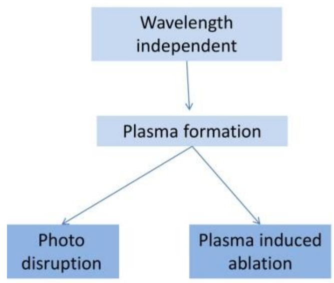
- What follows after the interaction between lasers and tissue is briefed in Figure 3, Table 2. [2,18,19]

Laser tissue interaction can be classified as:

i. Wavelength dependent (Figure 3.1)
ii. Wavelength Independent (Figure 3.2)

Interaction of light with biological tissue (wavelength dependent mechanism) (Figure 3.1)





Interaction of light with biological tissue (wavelenght independent mechanism) (figure 3.2)

Temperature	Biological effects
37°C	Normal
45-50°C	Hyperthermia, Reduction of enzyme activity, Cell immobility
60-80°C	Denaturation of proteins and collagen; Coagulation
100°C	Vaporization, Thermal decomposition(ablation)
>100°C	Carbonization
>300°	Melting

Table 2: Effect of laser temperature on dental hard tissue

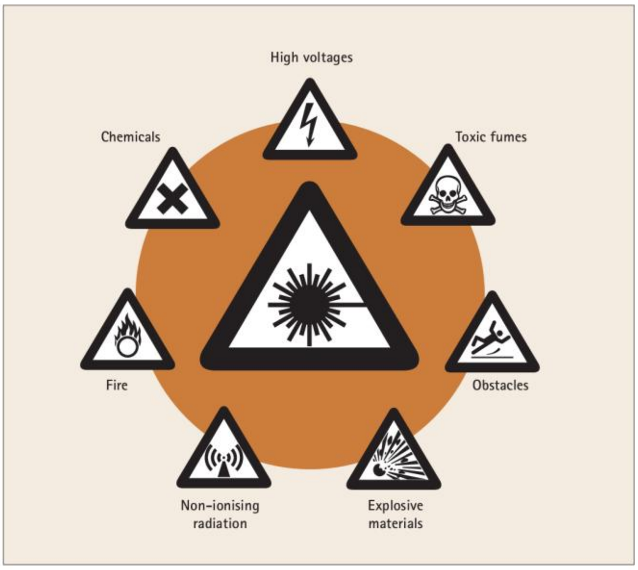
Lasers: Health Hazards, Risks and Safety protocols

Following protocols should be followed for safety from lasers beam during use of lasers: (Figure 3.3 – 3.5)

1) Safety Google to be worn by both patients, operator including the assistant.
2) Lock the room during treatment.
3) Never look directly into the beam or point it at the eyes.
4) Never point the beam at any person or area except the site to be treated.
5) Never use the Laser in place of inflammable anesthesia.
6) Never step on / abruptly bend a fiber optic cable.
7) Don't move the laser while treatment is going on.

Injury from lasers can be five broad types:

Ocular injury, Tissue hazard, Environmental hazard, Electrical, and Combustion hazard.
A Laser room should always have the "Hazard sign", for the safety of common patients.[20, 21]



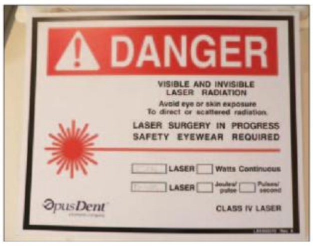


Figure 3.3: Safety considerations with dental lasers

	Short time exposure (t)		Long time exposure (T)		Specular reflection of beam	Skin exposure to beam
	Magnified exposure	Unprotected eye	Magnified exposure	Unprotected eye		
I	✓	✓	✓	✓	✓	✓
IM	⚠ (max)	✓	⚠ (max)	✓	✓	✓
II	✓	✓	⚠ (max)	⚠ (max)	✓	✓
IIM	⚠ (max)	✓	⚠ (max)	⚠ (max)	✓	✓
IIIR	⚠	⚠	⚠ (max)	⚠ (max)	✓	✓
IIIB	⚠ (max)	⚠ (max)	⚠ (max)	⚠ (max)	⚠	⚠
IV	⚠ (max)	⚠ (max)	⚠ (max)	⚠ (max)	⚠ (max)	⚠ (max)

✓ No risk from exposure to laser beam; ⚠ Caution required to prevent exposure to beam; ⚠ (max) Maximal protection required. Laser beam is dangerous

Figure 3.4: Laser regulation and safety in general dental practice

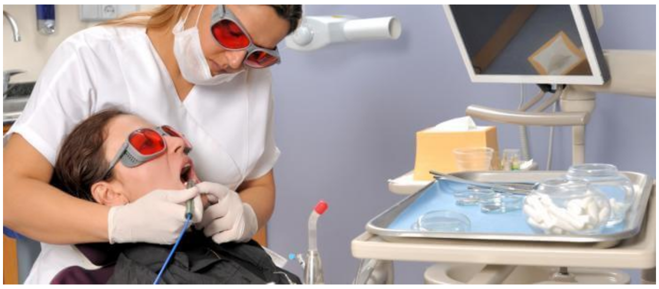


Figure 3.5: Safety in dental laser

Lasers used in Periodontics:

1) Argon Lasers

Argon lasers are soft tissue lasers that operate between wavelength 488 nm - 514 nm. The laser beam is absorbed maximum in red pigments & tissues with abundant Hb. It is poorly absorbed by HA and water, thus inflicting no injury or harm to the hard tissues like bones, teeth, or enamel. The tissue effect of this laser is thermal in nature.[22-24]

Specific applications of argon lasers in dentistry include:

a) Root planning & curettage-photocoagulation and vaporization of granulation tissues and debris in periodontal pockets.
b) At a temperature between 90-100°C soft tissue lasers coagulate the blood vessels and remove the sulcular depth. This acts as an excellent hemostatic and coagulation agent.
c) The soft tissue lasers are used to excise oral lesions like benign growth, enlargements, and other necrotic tissues, thus disinfecting the wound.
   Lasers may be used for arterial welding.
d) Advantage of argon lasers: it preserves the mechanical properties of the tissue and decreases hyperplasia.

2) Diode Laser:

These are the most commonly used lasers in dental schools and clinics. It operated between a wavelength of 800-980 nm i.e., the invisible spectrum of light. As such, it is well absorbed by the soft tissue and poorly by hard tissue. It is quite affordable and portable. Diode lasers are semiconductor lasers with a Gallium Arsenide chip and Aluminium, which changes electric energy to light energy. There is no special power source or cooling or heating system related to this laser.[24-26]

Initiation of diode Lasers: the diode laser fibers are initiated by burning to articulate paper on the tip. The initiation causes light energy to be absorbed by the burnt material on the tip, effectively making it a hot piece of Quartz. The laser energy cuts indirectly by heating the tip of the fiber optic.

Diode lasers don't have enough peak power to efficiently cut tissues on their own without initiation. So, when one describes "Laser dentistry" as light interacting with tissue, then diode procedures wouldn't be considered as one.

The tip used in diode laser is Biolase (Pre initiated tips).

Nd: YAG laser

The mode of action of this laser is Coagulation (100°C). It operates at a wavelength of 1.06 µm. This laser can be combined with CO_2 or KTP lasers forming Combo Lasers.

The main indication of this laser is the coagulation of very vascular lesions or near major vascular blood vessels (due to its excellent hemostatic ability). Special care should be taken while using this laser due to its hazardous effect on the retina. If the beam gets into naked eyes, it'll cause inadvertent blood loss and blindness.

In 1995 FDA gave it clearance for gingival surgery.[27]

Er: YAG lasers: has an active medium of a solid crystal of yttrium aluminum garnet doped with erbium. Erbium (Cr: YSGG; YAG) lasers aids in caries removal. It's a hard tissue laser, so pulpal damage is minimum. These Erbium lasers have a strong anesthetic effect on oral tissues, hence the use of analgesia isn't indicated. These lasers aids in the removal of endotoxins from the root surface providing anti-microbial benefits.[28, 29]

Ho: YAG lasers: Holmium lasers operate at a wavelength of 2102 µm. it is mainly used for soft tissue excision and frequently indicated for arthroscopy of TMJ. Compared to CO_2 lasers, Ho: YAG lasers offer greater hemostasis and are safer and more effective to use in bone & cartilage.[30]

KTP (Potassium Titanyl Phosphate) Lasers:
It operates at a specific wavelength of 0.53 µm. Mainly indicated for use in vascular lesions and tonsillectomy.[31]

CO_2 Lasers:
It operates at a wavelength of 10.6 µm. The mode of operation is vaporization and cutting (100°C). It is the first Laser to be used routinely for soft tissue surgery in dentistry.

Indicated in patients with oral lesions and blood dyscrasias. It's also used in the excision of premalignant lesions, biopsy, Hemi glossectomy, and macrovascular/ microneural diseases.[32-34]
In a research article, the use of CO_2 Lasers was reported to be destructive as it causes loss of the odontoblastic layer of dentin.[35]

Commercially used Lasers:

- **Waterlase system** is a revolutionary dental device that uses laser energized water to cut or ablate soft and hard tissue.
- **Periowave™**, a photodynamic disinfection system, utilizes nontoxic dye (photosensitizer) in combination with low-intensity lasers enabling singlet oxygen molecules to destroy bacteria (Thomas, 2006).

Lasers Diagnostics:

- **Laser doppler Flowmetry**-used to monitor the gingival and pulpal blood flow and to assess the tooth vitality.
- **Laser doppler Vibrometer**-used to measure tooth mobility.

- **Laser Fluorescence (Diagnodent)-**used for caries detection.

3) Applications of lasers in Dentistry

1) Dentinal Hypersensitivity (DH)

The prevalence of dentinal hypersensitivity varies from 11.3-11.7 % on average. The incidence rate is much higher in patients with periodontitis (57% average). This condition affects patients irrespective of age, gender, and race.

In the mid-1980s, Laser was first introduced as a potential approach to treat DHs. LLLT (Low-Level Laser Therapy) has shown hope in the treatment of hypersensitivity. The treatment of lasers combined with a desensitizing material induces changes in the nerve transmission of the dental pulp, thus giving relief.

Lasers can also be combined with fluoride treatment for DH. Several fluoride agents like NaF and SnF_2 have shown to be effective when used with lasers. The use of diode lasers with fluoride is shown to enhance the therapy effectiveness by 20 % alone compared with lasers alone.[36,37]

Controversy: Placebo effect-A strong placebo effect is seen in clinical trials with Lasers in cases of DH.

Non-surgical therapy: soft tissue lasers used in dental treatment are ineffective in NSPT. Lasers like CO_2, Nd: YAG has limitations as it causes incomplete debridement of plaque, calculus, and elimination of pocket lining.

Studies have shown that Lasers become relatively ineffective with the increase in pocket depth.

Lasers used are Diode, Nd: YAG, Er: YAG, and CO_2 lasers.

A unique task of lasers over conventional scalers is, they can be used for subgingival calculus detection by tactile sensation. Er: YAG lasers have a fluorescent feedback system for calculus detection. The rationale behind it is that: different parts of calculus, plaque, and hard tissues have different fluorescent emission properties when subjected to irradiation with a 655 nm diode laser.[38,39, 40]

Root biomodification: a lot of studies are done to determine the degree of effectiveness of using lasers in bacterial reduction and detoxifying root surfaces.[41, 42]

Low-level laser therapy:
In 1903, N. R. Finesen the father of modern phototherapy reports the positive outcome of treating lupus vulgaris with low-level UV light. Later, studies began to be conducted to access the results of LLLT on cell cultures, organs, and tissues.

In general, smaller and less expensive lasers operate at the 1-500-milliwatt range for LLLT or “Therapeutic Laser Therapy”. The therapeutic energy range is 1-10 Joules / Point.

All commercially available LLT are variants of Ga, Al, Ar which come under infra-red spectrums.

Biostimulation effect of LLLT: The following outcomes have been seen with LLLT on soft and hard tissues: [43-46]

a) Reduction of discomfort and pain.
b) Promotion of wound healing.
c) Bone regeneration.
d) Suppression of the inflammatory process.
e) Activation of gingival and PDL fibroblasts, growth factor release.
f) Alterations of gene expression of inflammatory cytokines.
g) Photo biostimulation.

LANAP (Laser-assisted new attachment procedure): proposed by Gold and Villardi in 1994. It is a safe procedure where Nd: YAG lasers are used for the removal of pocket lining epithelium without damaging the underlying connective tissue. This technique is approved by ADA for use for true regeneration.[47](Figure 3.6)

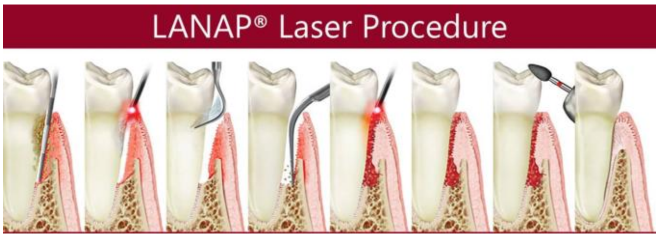


Figure 3.6: LANAP procedure

Yukna et. al., 2007 reported a histological study case series that showed that LANAP induces new cementum formation along with new connective tissue on the previously diseased root surface.[48]

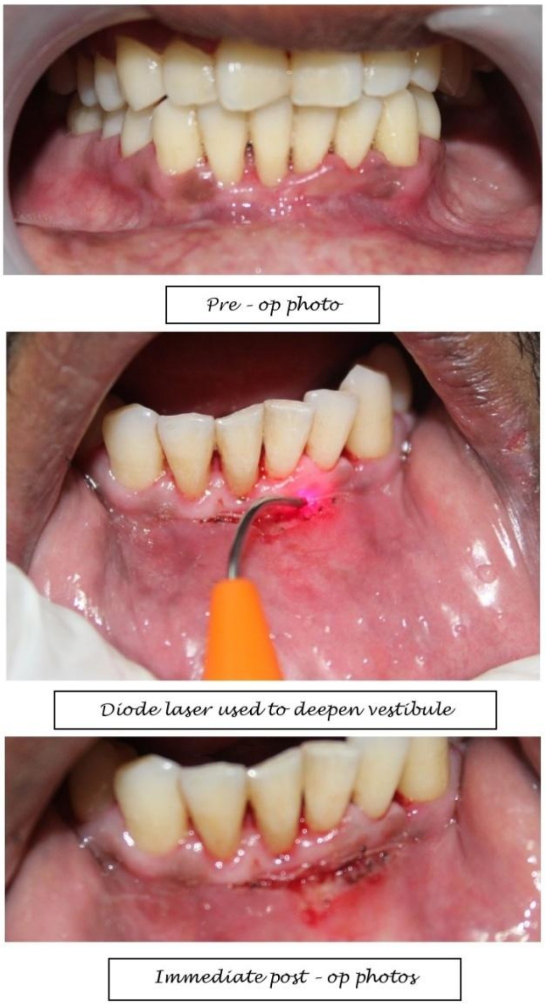
Surgical pocket therapy using Lasers: CO_2 and Erbium lasers are used in periodontal surgical procedures for calculus removal, osseous surgery, detoxification of root surface & bone, and granulation tissue removal. The edge of using lasers over conventional therapy is better accessed in furcation areas, hemostasis, less post-operative discomfort, and rapid healing.[49,50]

Gingivectomy: Lasers give the clinician better tactile control and better visibility due to the bloodless field of treatment. Further, the patient apprehension is low with lasers as it's much comfortable than conventional treatment with anesthesia, blade, and sutures. In case of availability, lasers are preferred over the conventional procedure for restorative purposes and gingival hyperplasia cases.

- Crown lengthening: lasers can safely be used for clinical crown lengthening without reflection of the flap in both esthetic and prosthetic cases.
- Frenectomy: laser frenectomy may be performed without infiltration and with optimum post-operative healing.
- Tissue pigmentation reduction: Laser is preferred over scalpel for depigmentation. (Figure 4)
- Implant therapy: Management of periimplantitis

For scaling in implant sites, plastic curettes are usually used along with antibiotics. Laser is another alternate option. The benefits of using lasers are disinfection and decontamination of implant surface along with granulation tissue removal. Usually, diode, erbium, or CO_2 lasers are used. Nd: YAG lasers are not recommended due to pitting in the implant surface.[51, 52, 53]

Laser assisted ~Frenectomy with Vestibuloplasty (Figure 4)



Photodynamic therapy (PDT):

The main objective of this therapy is to eliminate bacterial deposits from surfaces of metals and dental materials. Its edge over the conventional methods is because it's accessible to any anatomic complexity of roots and effective even in deep periodontal pockets.

Mechanism of action: PDT involves three components: light, a photosensitizer, and oxygen. When a photosensitizer is delivered to a patient and irradiated with a beam of suitable wavelength, the electrons go from their ground state to an excited state. This excited state can then decay back to its earlier ground state or form a higher energy triplet state. The triplet state photosensitizer can react with two different biomolecules and enter two different pathways.

The type I pathway involves electron/hydrogen transfer directly from the photosensitizer producing ions or causes electrons/ hydrogen removal from a substrate molecule to form a free radical. These radicals then rapidly react with oxygen, resulting in the formation of highly reactive oxygen species (superoxide, hydroxyl radicals, and hydrogen peroxide).

The type II pathway: In this phase, the triplet state photosensitizer reacts with oxygen to produce an electronically excited and highly reactive state of oxygen, known as singlet oxygen ($^1O_2$). Singlet oxygen can interact with a large number of biological substrates inducing oxidative damage on the cell membrane and cell wall. Singlet oxygen is effective against viruses, bacteria, and fungi. It has a short lifetime in the biological system and a shorter radius of action (0.02 mm).

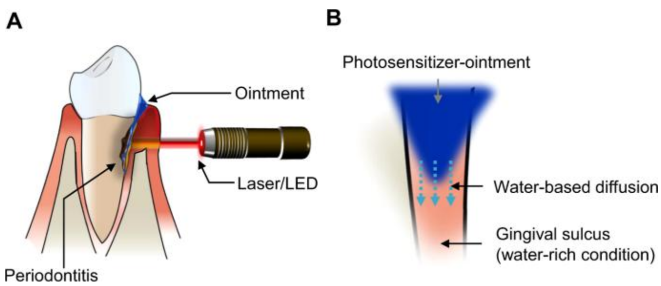


Figure 5.1.: Non-Invasive Photodynamic Therapy against - Periodontitis-causing Bacteria

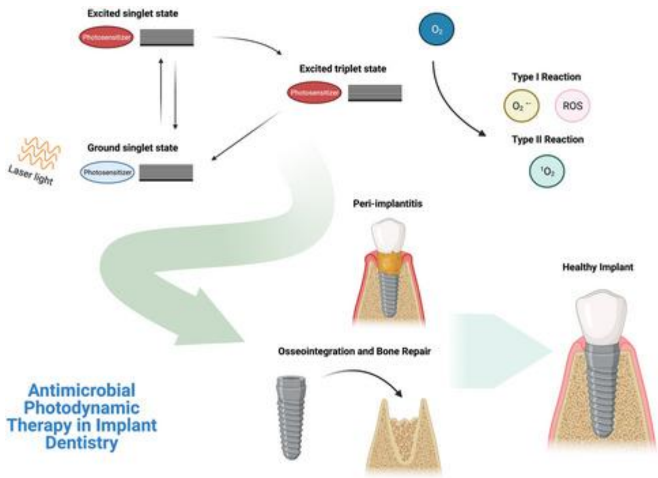


Figure 5.2: Photodynamic Therapy for Biomodulation and Disinfection in Implant Dentistry

Hence, this reaction takes place in a confined space, leading to localized response thus, making it ideal for application to localized sites without affecting the distant cells or organs. Thus, the type II reaction is accepted as the major pathway in microbial cell damage.[54, 55, 56]

Effects of laser on local site after periodontal therapy:
Pain relief: laser therapy blocks the pain signal from the site of injury to the brain. This reduces nerve sensitivity and pain perception. Lasers beam also increases the production and release of endorphins and enkephalins which are natural pain-relieving chemicals within our bodies.

Inflammatory reduction: Lasers stimulate the small arteries and lymph vessels, causing vasodilation. This lymphatic drainage is vital as it clears the swelling, edema from injury sites, and aids in the vital healing process.[4]

Accelerated tissue repair and wound healing: LLLT stimulates tissues to release growth factors and promotes a faster release of stem cell differentiation factors. This causes effective tissue healing and regeneration. It also induces the release of HSR (Heat shock response), HSP-70, and TGF β, which are key elements for cell & fiber formation.

As such LLLT is being increasingly used to remove cutaneous lesions, scars revision (hypertrophied and keloid scars) for tissue welding, and skin resurfacing and remodeling (wrinkle removal).[57]

2. Conclusion

Lasers have an extraordinary role in dentistry. When used congruously, lasers are efficient and crucial in sensitive cases where conventional methods may be risky. In patients with severe anxiety, stress, or medically compromised, lasers are better choices for symptomatic treatment in cases of Vestibuloplasty, operculectomy, and gingivectomy. It's bloodless, less painful, and slows better patient compliance. But despite all the hype and expectations, proper care should be taken to protect the eyes and soft tissues from laser damage, as the damage is irreversible. As Aaron Rose Says, "In right light at right time everything is extraordinary."

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