Review Article

Lasers in dentistry - Thinking ahead…

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Abstract:
Laser technology was introduced in the field of dentistry with a novel idea of overcoming few problems or drawbacks posed by the conventional methods. Theodore Maiman in 1960 introduced the first solid state ruby laser. Since then lasers have gained its popularity in different fields of dentistry. Laser in dentistry is now in vogue and now becoming a part of the dentist's armamentarium. This article gives an insight to the basics of laser physics, types of laser, mechanism of action, their interactions with biologic tissues and their advantage and disadvantage.

Keywords: Laser, dentistry, tissue interaction, precautions, effects.

Introduction

Laser is an acronym for **Light Amplification by Stimulated Emission of Radiation.** Laser is a type of electromagnetic wave generator, which differs from regular light in that it has a single wavelength and can be focussed in a very narrow beam making it more potent and accurate.[1, 2] Laser converts electromagnetic energy into thermal energy.[1] After being first introduced in the field of medicine and dentistry during 1960, lasers have gained popularity in dentistry from past few years in wide variety of procedures in different fields of dentistry. [2] Effects of laser depend on its type as well as on the type of tissue through which it transmits, absorbs, scatters or reflects the laser light. Lasers produce waves of photons which are specific to their wavelength. The photonic absorption within the target tissue results in an intracellular and/or intercellular change to produce the desired result and can result in damage to deeper structures.[2] Variety of lasers have enabled dentists to reduce patient's pain and stress and fear during treatment and has been used in treatment of various diseases.[3] Laser with different wave length and delivery system are being used in dentistry including restorative, periodontal, haemostatic property and surgical treatments. The present article summarises the application of lasers in the field of dentistry.

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History

Lasers work on the principle of stimulated emission theory proposed by Albert Einstein in 1917 based on the concept of spontaneous stimulated emission theory which was postulated by Neil Bohr in early 1900s. Theodore Maimam developed the first laser prototype in 1960 using ruby crystals stimulated by a flash lamp and mirrors to amplify the action of the laser on human caries, later on many lasers were created rapidly.[3] In 1962, laser was used in dentistry for the first time by Goldman. In 1965 Stern and Sognnaes reported that ruby lasers have a capacity to vaporize enamel and continuous thermal effect of it is known to damage the pulp.[4] Clinical research began soon after with the first usage of Carbon-di-oxide (CO_2) for the applications in oral surgical procedure in 1977, and got the FDA clearance in 1987. Later on in 1990, the first pulsed laser Neodymium-doped yttrium aluminium garnet (Nd: YAG) was designed specifically to dentistry. Later in 1997 FDA gave the clearance to the first dental hard tissue Er: YAG laser and the Er,Cr: YSGG a year later. Semiconductor based diode lasers also emerged in the late 1990s.[4] CO_2 and Nd: YAG were the most earlier lasers used in dentistry.[1]

Classification of Lasers

Different lasers are used in the field of dentistry and can be classified according material used, hardness, power and spectrum of light (Tables 1, 2, 3, 4).[1]

Table 1: Classification of Lasers according to physical construction.[1]

Sl. No.	Physical Construction	Laser
1.	Gas	Carbon dioxide, Argon, Helium/neon
2.	Liquid	Not so far in clinical use
3.	Solid/ Semiconductor	Nd: YAG, Er: YAG, Er,Cr: YSGG, Ho :YAG, Diode

Table 2: Classification of Lasers according to hardness.[1]

Sl. No	Soft lasers	Hard lasers (surgical)
1.	Cold (athermic) energy emitted as wavelengths and Stimulate cellular activity	Shows good absorption by hydroxyapatite crystals and water making it more efficient on enamel and dentine
2.	Smaller and less expensive	Expensive
3.	Utilize diodes	Transmit their energy via a flexible fibre optic cable
4.	Aid healing of tissue, reduces inflammation, edema, and pain	Cut both soft and hard tissues
5.	Clinical application - Healing of localized osteitis, healing of aphthous ulcers, reduction of pain, and treatment of gingivitis	
	a. Argon lasers (Ar) b. Carbon-dioxide lasers (CO2) at 10.6 micro-meter c. Neodymium-doped yttrium aluminum garnet (Nd: YAG) d. Helium-neon (He-N) at 632.8 nm (red, visible) e. Gallium- arsenide (Ga-As) at 830 nm (infra-red, invisible)	a. Erbium, chromiummyttrium-slenium-gallium-garnet (Er,Cr: YSGG) b. Neodymiummyttrium-aluminum-perovskite (Nd:YAP) c. Holmiumyttrium-aluminum-garnet (Ho: YAG) at 2.1 micro-meter

Table 3: Classification of Lasers based on power.[2]

High-Power Lasers (Hard/Hot)	Intermediate-Power Lasers	Low-Power Lasers (Soft/Cold)
a. Lasers have an output power of more than 500 mW b. Lasers increase tissue kinetic energy and produce heat, resulting in a therapeutic effect through thermal interactions c. Effects include necrosis, carbonization, vaporization, coagulation and denaturation	a. Lasers have an output power of more than 250-500 mW b. Lasers leave their therapeutic effects without producing significant heat c. Intermediate lasers are used to shorten the length of treatment period and to accelerate the therapeutic effect	a. Lasers have an output power is less than 250 mW b. Lasers have no thermal effect on tissues and produce a reaction in cells through light, called photo-bio-stimulation or biochemical reaction

Table 4: Classification of Lasers based on light spectrum[1]

Sl. No.	Spectrum of Light	Wavelength	Laser
1.	UV Light	100 nm - 400 nm	Not used in dentistry
2.	Visible light	400 nm to 750 nm	Most commonly used in dentistry (Argon & Diagnodent Lasers)
3.	Infrared light	750 nm to 10000 nm	Most dental lasers are in this spectrum

Laser Unit [5, 6]

1. Active Medium:

The active medium can be gas, liquid or solid state where laser light is generated via a process called stimulated emission. The active medium typically denotes the name of the different types of lasers. For example: Carbon dioxide laser, Er: YAG laser and Nd: YAG laser.

2. Pumping mechanism:

External power source supplies energy continuously to excite (pump) the active medium so that stimulated emission can occur achieving a population inversion.

3. Optical resonator:

The active medium is positioned within an optical subsystem called the laser resonator. The resonator consists of two mirrors separated by the active medium in between. The mirrors are aligned and parallel to each other. On each end of the optical resonator the mirror reflects the excited photons produced by the excited active medium back and forth in a direction perpendicular to the mirror surfaces.

4. Cooling system:

Most of the power into the active medium is converted into laser energy and some of the power is converted into heat with resultant raise in the temperature of the active medium. So a cooling system is needed to ensure and maintain the temperature of the active medium below its maximum operating temperature.

5. Delivery system:

Laser energy is delivered to the target site by various delivery systems like Fiber-optic, Hollow waveguide (flexible) and articulated arm depending on the type of laser. Hard tissue lasers have hand pieces resembling a turbine which provide a familiar dental feel effect.

Mechanism of action of Lasers:

Lasers are the direct application of light energy with bio-modulatory capacity on tissues and cells. Photo acceptors (cytochrome-c oxidase) can absorb low level lasers irradiation and transfer it inside mitochondria in order to provide cell energy (ATP) which is the product cytochrome-c oxidase and Krebs cycle. Later on the stimulation of ATP synthesis results in increased cellular activity. Bio-modulatory effects of low level laser therapy results in macrophages, lymphocytes, fibroblasts, endothelial cells and keratinocytes proliferation as well as increase ATP synthesis and cell respiration, growth factors and release of other cytokines. Along with change of fibroblasts to myofibroblasts, change in inflammatory mediators level (histamine and prostaglandins); increase in oxygen transport and improve in glucose consumption; changes in cell membrane potential and permeability, sodium/potassium pump excitation and more calcium removal, vasodilatation, angiogenesis and collagen synthesis. [2]

Laser-Tissue Interactions

Laser tissue interactions depend on laser wavelength, its emission mode, heat capacity and on optical properties of the tissues such as pigmentation, mineral & water content. Laser beam is aimed at the tissue to produce a specific effect on the tissue interface. Any one of four interactions will take place at the tissue interface: absorption, reflection, scattering or transmission. [4, 7, 8] (Figure 1)

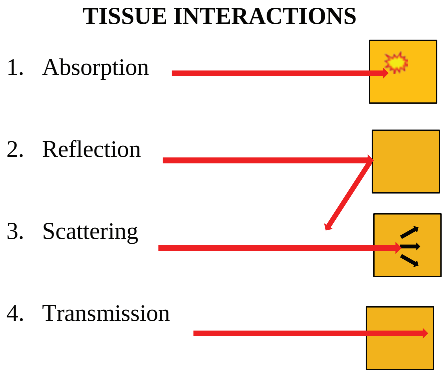

Figure 1: Tissue interactions of Lasers

1.Absorption- Specific characteristics (pigmentation/water content) of the tissue absorb the photons from the laser beam and the light energy is then converted into other forms of energy to perform the action. Shorter wavelengths (from about 500- 1000nm) are readily absorbed in pigmented tissue and blood elements whereas longer wavelengths are more interactive with water and hydroxyapatite

2.Reflection- Laser beam bounces off from the surface without any penetration or interaction. Reflection is usually an undesired effect. Example of reflection is found when Erbium lasers reflect off titanium allowing a safe trimming of gingiva around implant abutments.

3.Scattering-Laser energy enters the target tissue shows either shallow or deeper penetration & weakening the intended energy depending on type of tissue. Scattering of the laser beam could cause heat transfer to the tissue adjacent resulting in unwanted damage. 7 Deeper the penetration of laser energy, more the scattering and distribution in different directions would be useful in facilitating the curing of composite resin. This phenomenon is usually not helpful, but can help with certain wavelengths bio-stimulative properties.

4.Transmission- Laser energy can pass through superficial tissues to interact with deeper areas. This effect is highly dependent on the wavelength of laser light. Water is relatively transparent to the diode and Nd: YAG wavelengths, whereas tissue fluids readily absorb Erbium and Carbon Dioxide at the outer surface with little energy transmitted to adjacent tissues. Nd: YAG and diode lasers showing deeper penetration are an example of tissue transmission.

Biological effects [4,7]

Laser beam when enters or in contact with the tissue biological changes can be seen within the tissue or adjacent to it. Most important biological effects are fluorescence, photo-thermal, photo-disruptive, photochemical and photo-biomodulative.

Fluorescence effects: Diagnostic lasers devices at certain wavelength tend to fluoresce the actively carious region depending on the size of the lesion. This effect is useful in diagnosing and managing early carious lesions.

Photo-thermal effects: Laser energy is absorbed by the chromophores present within the tissue with the production of heat. Produced heat will perform the work such as incising tissue or coagulating blood. Photo-thermal effect occurs mostly during the performance of soft tissue procedures with lasers.

Photo-disruptive/Photo-acoustic effects: Hard tissues are removed through a process known as photo-disruptive ablation. Laser beam of high power interact with the tissue water molecule resulting in a rapid thermal expansion of the water molecules. This further disrupts the enamel and bony matrices. Tooth structure and bone are not vaporized but pulverized instead through the photomechanical ablation process.

Photochemical: Photon energy released from the laser beam results in the chemical changes within the tissues like composite curing, breaking of chemical bond and production of oxygen radical for the disinfection of the periodontal pockets and root canals.

Photo-biomodulation/Photo-biostimulation: Lasers beams with different wavelength have an ability to speed wound healing, increased collagen activity, increase circulation, reduce oedema, anti-inflammatory and minimize pain. Bio-stimulation is used dentistry to reduce postoperative discomfort and to treat illnesses like recurrent herpes and aphthous stomatitis.

Applications of lasers in Dentistry

Lasers are widely used in dentistry for cavity and root canal preparations, scaling and root planning, gingival and periodontal surgeries, coagulation and haemostasis, biopsies, excision of tongue lesions, TMJ disorders, exposure of implants and pre-prosthetic surgery.[3] (Table 5)

Table 5: Applications of Lasers in various branches of Dentistry.

Sl. No.	Applications in Branches	Soft tissue	Hard tissue
1.	Oral Medicine and Diagnosis	• Dysplastic changes within the oral mucosa can be detected at the earliest by the use of blue light by the Velescope • Aphthous ulcers can be treated	• Detection of caries & bacteria using a red light which fluorescence through enamel/ dentine gives digital score for dental caries detection (Diagnodent)
2.	Oral and Maxillo-facial Surgery	• Incisions and draining of abscesses • Removal(Incision/Excision) of fibrotic tissue, inflamed, hypertrophic / hyperplastic tissues, gingival growths, mucoceles, cysts, precancerous lesions, benign tumours, and other non-haemangioma type of lesions • Scar corrections • Exposure of soft-tissue impacted teeth	• Malformations • Pre-prosthetic surgeries • Re-contouring of bone
3.	Oral & Maxillofacial Pathology	• Bacterial decontamination • Biopsy- incision and excision	
4.	Applications in Orthodontics	• Aesthetic gingival recontouring • Soft tissue crown lengthening • Tissue removal at the site for mini screw	• Temporo-mandibular joint discomfort
5.	Applications in Conservative Dentistry & Endodontics		• Caries detection (including residual caries) • Caries removal & cavity preparation • Pit and fissure sealants • Dentinal Hypersensitivity • Sterilization & cleaning of root canal • Root canal preparation • Pulp Capping & Pulpotomy • Laser etching • Removal of defective composite and glass ionomer restorations
6.	Applications in Prosthodontics	• Gingival retraction for impressions	• Crown lengthening • Implant exposure
7.	Applications in Pedodontics (Article 8_nitin)		• Prevention of teeth from devitalisation • Haemorrhage control • Sterilization (Destroys oral pathogens at the site of trauma) • Healing during soft tissue trauma or facial lacerations • Healing of aphthous ulcer & shortening the duration of the herpes labialis lesion • Controlling Gag Reflex
8.	Applications in Periodontics	• Sub-gingival debridement • Laser assisted soft tissue curettage, flap & periapical surgery • Removal of granulation tissue • Gingivectomy, Operculectomy and Frenectomy (Lingual or Maxillary frenum) • Gingivoplasty & vestibuloplasty • Treating hyperpigmentation and metal tattoos	• Osseous re-contouring as well as in implant surgery and its maintenance • Treatment of ankyloglossia
9.	General	• Haemostasis • To check the vitality of pulp • Pulpal analgesia	

Histological alterations seen in laser treated tissues[3]

1. Changes seen in epithelium

- Blisters formation
- Clefts formation
- Erosions
- Any intraepithelial or sub-epithelial loss of attachment

2. Connective tissue changes

- Carbonization
- Desiccation expressed as dense eosinophilic layer

3. Vascular changes

- Intraluminal clotted erythrocytes
- Vascular stasis with presence of gathered erythrocytes
- Thrombosed or collapsed blood or lymphatic vessels

4. Changes in cytological morphology

- Hyperchromic cytoplasm
- Cell fusion
- Loss of normal cell adhesion
- Presence of hyperchromatic & pyknotic / spindle-shaped nuclei

Laser Hazards and its Safety [4, 8, 9]

Proper safety procedures should be followed to reduce the possibility of unwanted exposure of patient and personnel to laser radiation while dealing with laser instruments.

1. Ocular Hazard: Potential injury to the eye can occur either by direct emission from laser or from the reflection from mirror-like surfaces. Dental instruments have been capable of producing reflections that may result in tissue damage to both the operator and the patient.

Safety Precaution: The use of carbonized or non-reflective instruments is recommended during laser treatment to prevent damage to the non-target tissues. Patient, clinician, entire surgical team and any observers must wear protective eyewear specific for the wavelength of laser to be used.

2.Tissue Damage: Laser induced damage to the non-targeted tissue (oral and skin) can result from thermal interaction of radiant energy with tissue proteins. Temperature elevations of 21ºC above normal body temperature (37ºC) can produce cell destruction by denaturation of cellular enzymes and structural proteins, which interrupts basic metabolic processes.

Safety Precaution: Laser use should be confined to controlled areas with restricted access. Non-targeted tissue or the delicate oral mucosa is protected from accidental laser beam through the use of wet clothes or gauze packs. Hard tissues are protected during the soft tissue surgeries using the silver foil in between gingiva and teeth. Use of protective laser curtains prevents the accidental exposures to spectators.

3.Plume Control: Laser procedures produces a smoke or plume generated through the thermal interaction of surgical lasers through tissue or through the accidental escape of toxic chemical, gases and micro-flora (fluorine, hydrochloride) from the laser itself. Safety Precaution: Standard high-speed evacuation chamber is adequate to control the smoke or plume as well as good quality masks should be worn by the clinicians.

4.Combustion Hazards: Laser pose a significant combustion hazard in the presence of flammable objects like solids, liquids and gases used in dental surgical setting. Toxic fumes are released as a result of combustion of flammable materials.

Safety Precaution: Should avoid the use of flammable and explosive liquid or gases in the operating room as laser energy generates heat. Flammable materials like surgical drapes and gauze sponges may be soaked in sterile saline to reduce the possibility of burning by accidental exposure to the laser beam. The use of flame resistant materials like Poly Vinyl Chloride or red rubber or silastic intubation tube wrapped with aluminium sheet, wax spatula or periosteal elevator can be effective during soft tissue lasing.

5.Electrical Hazards: Most laser systems involve high potential, high current electrical supplies leading to shock and explosion hazards.

Safety Precaution: Safe manufacturing practices offer adequate protection from these hazards. Insulation, shielding, grounding and housing of high voltage electrical components provide adequate protection under most circumstances from electrical injury. Most manufacturers provide a cover or metal hood to prevent accidental activation of the laser beam. The floor of the operating room must be kept dry while operating with laser unit. It is a good practice to have at least two persons in an area while working on high energy power systems.

6.Warning Sign: At or nearing the operating area, warning signs should be visible and clearly mentioned containing the words ‘Danger’ and ‘Laser Radiation.

7.Sharps: Scored laser tips of quartz fibres are sharps and need to be disposed properly.

Advantage and disadvantage of Lasers:

Advantages/Benefits: [3, 7, 10]

1. Reduction in operator chair time in comparison for similar restorative procedures
2. Selectively and precisely interact with diseased tissues
3. Dry surgical field and better visualization.
4. Tissue surface sterilization or decontaminating property of laser and bactericidal properties on the tissue with a reduced need of antibiotics
5. Good homeostasis with the reduced need for sutures
6. Decreased swelling, oedema, scarring and less thermal necrosis of adjacent tissue.
7. Reduced amount of local anaesthetics for soft tissue treatments
8. Decreased pain
9. Faster healing response/Accelerated wound healing with decreased post-operative discomfort and reduced need for analgesics
10. Increased patient acceptance.
11. Minimal mechanical trauma
12. Less thermal necrosis of adjacent tissues is produced with lasers compared to electrosurgical instruments
13. Negotiates folds in tissues
14. Elimination of the high-speed drill with its associated vibrations, noise, smell and fear
15. Osseous tissue removal and contouring

Disadvantages / Limitations: [3, 7, 10]

1. Relatively high in cost to purchase equipment & implement technology
2. Operations of lasers require specialized training & education in various clinical applications
3. Dental instruments mainly used are both side and end cutting thus; a modification of clinical technique is required.

4. No single wavelength will optimally treat all dental disease, so more than one laser needed for various procedure
5. There is inability to remove metallic and cast-porcelain defective restorations by erbium family lasers.
6. Hard tissue removal with laser is not as fast as a rotary bur
7. Harmful to eyes so the entire professional team should wear the specific wavelength eyewear and are harmful to skin as well.
8. In immune-compromised patients, when providing soft tissue treatment of viral lesions, there is a potential risk of disease transmission from laser generated aerosol

Conclusion

Laser, a captivating technology is in rapid progress since the past few decades and one of the best inventions of the 20th century. Lasers are not only used to create aesthetics, for diagnosis and removal of diseased tissue but can also be used for repair and regeneration of the tissue. Clinician should have the knowledge of the physical characteristics, wavelengths of laser and their interaction with the biological tissues along with complete training course and then proceed through learning curve at comfortable pace. Lasers can prove to be a blessing in disguise if used safely and properly.

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