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The amazing spectrum of light – LASER

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A B S T R A C T

"In right light at right time everything is extraordinary"- says Aaron Rose. This is very true with respect to lasers. Discovery of lasers from the spectrum of light has revolutionized the technology in many fields. The word "LASER" means Light Amplification by Stimulated Emission of Radiation. They offer many useful clinical applications for general dentists in the diagnosis and treatment of patients. There are many clinical, aesthetic, and psychological reasons to use lasers. Herein we present a brief overview of "THE AMAZING SPECTRUM OF LIGHT".

1. Introduction

Theodore Maiman, in 1960, developed the first working laser device, with Hughes Aircraft Corporation, which emitted a deep red-colored beam from a ruby crystal [1]. Dr. Leon Goldman, a dermatologist was experimenting with tattoo removal using the ruby laser. He focused two pulses of that red light on a tooth of his dentist brother, resulting in painless surface crazing of the enamel [2].

In 1970s and 1980s CO_2, neodymium YAG (Nd:YAG) were studied and they are thought to have better interaction with dental hard tissues. The medical community in 1970s had begun to incorporate lasers into the soft-tissue procedures. Frame, Pick and Pecaro stated the benefits of CO_2 laser treatment of oral soft-tissue lesions and periodontal procedures [3,4,5]. In 1989, Myers and Myers received permission from the US Food and Drug Administration to sell a dedicated dental laser, the Nd:YAG. Since then, numerous instruments have been made available for dental use, and more are being developed [6].

At present, lasers are indicated for a variety of dental procedures. The clinician must be familiar with the fundamentals of laser physics and tissue interaction so that the proper laser device is used to obtain the treatment objective safely and effectively.

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2. Classification

2.1. Based on power, lasers can be classified into the following three categories [7];

2.1.1 High - Power Lasers (Hard, Hot)
These produce heat by increasing the tissue kinetic energy. Because of this, they produce therapeutic effects through thermal interactions like necrosis, carbonization, vaporization, coagulation and denaturation. The output power of these lasers is usually more than 500 mW.

2.1.2 Intermediate - Power Lasers
These produce therapeutic effects without producing significant heat. They have output powers ranging from 250-500 mW.

2.1.3 Low - Power Lasers (Soft, Cold)
They have no thermal effect on tissues. They produce reaction in cells through light by a process called photo bio-stimulation or photo biochemical reaction. These have output power less than 250 mW.

2.2 Based on form, lasers are further classified as [1];
2.2.1 Gas lasers
- Argon
- Carbon-dioxide

2.2.2 Liquid
- Dyes

2.2.3 Solid
- Nd:YAG
- Erbium: yttrium aluminum garnet (Er: YAG)
- Diode

2.2.4 Semiconductor
- Hybrid silicon laser

2.2.5 Excimers
- Argon-fluoride
- Krypton-fluoride
- Xenon-fluoride

2.3 Classification based on light spectrum [8]
- UV Light spectrum ranging from 100nm–400nm.
- Visible light spectrum ranging from 400nm- 750 nm.
- Infrared light spectrum ranging from 750nm-10000 nm.

2.4 Lasers are also classified as soft lasers and hard lasers [8]

2.4.1 Soft lasers are believed to stimulate cellular activity. The Clinical application includes healing aphthous ulcers, healing localized osteitis, treatment of gingivitis and reduction of pain. The currently used soft lasers are Gallium- arsenide (Ga-As) and Helium-neon (He-N).

2.4.2 Hard lasers (surgical) can cut both soft tissues and hard tissues. Latest variety of hard lasers can transmit their energy through a flexible fiber optic cable. Currently used hard lasers are Argon lasers (Ar), Carbon-dioxide lasers (CO2), Neodymium-doped yttrium aluminum garnet (Nd:YAG), Neodymiummyttrium-aluminum-perovskite (Nd:YAP), Erbium, chromium, yttrium-slenium-gallium-garnet (Er,Cr:YSGG), and Holmiumyttrium-aluminum-garnet (Ho:YAG).

3. Mechanism of action

Laser is a monochromatic light and consists of a single wavelength. It has three principal parts: An energy source, an active lasing medium, and two or more mirrors that form an optical cavity or resonator. Pumping mechanism such as a flash-lamp strobe device, an electrical current, or an electrical coil supplies energy to laser system for amplification. The energy thus produced is pumped into an active medium which is contained in an optical resonator, producing a spontaneous emission of photons. Consequently, amplification by stimulated emission takes place when the photons are reflected back and forth through the active medium by the highly reflective surfaces of the optical resonator, prior to their exit via output coupler. The laser light in dental lasers is delivered via fiber-optic cable, hollow waveguide, or articulated arm. A cooling system, focusing lens and controls complete the system. The properties of the laser are primarily determined by the composition of an active medium, which can be a gas, a crystal, or a solid-state semiconductor.

The energy produced by a laser light may have different interactions with the target tissue like Transmission, Absorption, Scattering, and Reflection. Absorption results in elevation of temperature thereby producing photochemical effects depending on the water content of the tissues. Vaporization of the water within the tissue occurs when a temperature of 100°C is reached. This process is called ablation. At temperatures below 100°C and above approximately 60°C, there is no vaporization of the underlying tissue whereas proteins begin to denature. Conversely, at temperatures above 200°C, the tissue is dehydrated and then burned, resulting in carbonization [9,10].

Absorbers of light are known as chromophores. They have a specific affinity for certain wavelengths of light. The primary chromophores in the intraoral soft tissue are Hemoglobin, Melanin and Water. Whereas, in dental hard tissues Water and Hydroxyapatite constitute chromophores. With respect to these primary tissue components different laser wavelengths have different absorption coefficients making the laser selection procedure-dependent [11,12].

4. Common types of lasers in dentistry

4.1 Argon lasers

These lasers have ionized argon as their active medium and deliver laser light in continuous wave and gated pulsed modes. Two wavelengths are being used in dentistry: 488 nm (blue) and 514 nm (blue green). These two wavelengths are poorly absorbed by the enamel and dentin. This provides an advantage during cutting and sculpting gingival tissues as they don't cause any damage to the tooth surface. Both wavelengths can be used as an aid for caries detection. When the argon laser light illuminates the tooth, the carious area appears as a dark orange-red color discriminating it from the surrounding healthy structures [1].

4.2 Diode lasers

These are manufactured from semiconductor crystals made from a combination of aluminum (wave length of 800 nm) or indium (900 nm), gallium and arsenic. These wavelengths can penetrate deep into the mucosa and they are highly attenuated by the pigmented tissue. These lasers are excellent for soft tissue surgical procedures like gingivoplasty, sulcular debridement and deeper coagulation process on gingival and mucosa as they are poorly absorbed by the dental hard tissue. These lasers can stimulate fibroblastic proliferation when operated at low energy levels[13].

4.3 Nd-YAG Lasers

These lasers have garnet crystal as the solid active medium combined with rare earth elements like aluminum and yttrium, doped with neodymium ions. They have wavelength of 1064 nm which is indicated for various soft-tissue procedures. This laser provides good hemostasis and thereby a clear operating field during soft-tissue procedures. This laser is also indicated for the removal of incipient. These lasers can penetrate several millimeters which can be used for treatment of aphthous ulcers and pulpal analgesia when used in a non- contact, defocused mode [14].

4.4 The Erbium family lasers

They consists of Erbium Cr:YSGG, Erbium:YAG.

4.4.1 Erbium:YAG laser: It's been used on hard tissues like enamel, cementum and bone but not extensively on soft tissues. Its wavelength of 2,940 nm is ideal for absorption by hydroxyapatite crystals and water thereby making it more efficient in ablating enamel and dentine. There is no marked thermal effect on tissues of this laser because the energy produced at this wavelength is absorbed by water and thus there is minimal rise in temperature. In the fiber optic delivery system helium neon laser is used as aiming beam.

4.4.2 Er:Cr:YSGG laser (Erbium: Chromium: YSGG): It is also known as water pulsed laser. It works on a power range of 0-6 W with wavelength 2.78 microns. It works by Hydro-kinetic tissue cutting system to energize water for the use on soft and hard tissues. The laser energy is delivered through a flexible fiber optic system. The laser energy excites the fiber and encounters a mist of water droplets. These droplets absorb energy and are instantly reduced to particulates and propelled with such force that they are capable of cutting hydroxyl-apatite crystals of enamel and the osseous skeleton of the bone. The energized water removes hard tissue with great efficiency [8].

4.5 CO_2 lasers

These lasers contain a gaseous mixture with Carbon-dioxide molecules which helps in producing a beam of infrared light. The light energy, with a wavelength of 10,600 nm, is absorbed by water and is delivered in gated pulsed or continuous mode through a hollow tube-like wave guide. The wavelength of carbon-dioxide lasers is useful in cutting and coagulation of soft tissue. Because of its limited penetration depth this laser is indicated for the treatment of mucosal lesions. Pain usually is minimal to none postoperatively. Delayed wound healing and loss of tactile sensation are the major disadvantages of this lasers [15].

5. Applications of lasers in dentistry

5.1 Soft tissue applications [16]

5.1.1 Disinfection using lasers

Oxygen-releasing dyes are photochemically activated with low power laser energy that causes membrane and DNA damage to the microorganisms. This technique can be performed using a system of visible red semiconductor diode lasers and tolonium chloride dye. This technique has been effective in killing bacteria in complex biofilms, such as subgingival plaque, which are typically resistant to the action of antimicrobial agents and can be made species-specific by tagging the dye with monoclonal antibodies. This dye can be applied effectively for killing both Gram-positive and Gram-negative bacteria, fungi, and viruses. The major clinical applications include disinfection of root canals, deep carious lesions, periodontal pockets and sites of peri-implantitis.

5.1.2 Wound healing

Low doses of laser application like 2 J/cm^2 stimulates proliferation, whereas suppressive action is seen at high doses like 16 J/cm^2. In a culture of gingival fibroblasts treatment with Low-level laser treatment (LLLT) has shown to induce transformation in myofibroblasts which are useful in wound contraction as early as 24 hours' post laser treatment. There have been recorded positive effects of LLLT on the healing of lesions of recurrent aphthous stomatitis. There are few cases, which show that LLLT promotes healing and dentinogenesis following pulpotomy.

5.1.3 Photodynamic therapy (PDT) for malignancies

This therapy has been employed in the treatment of malignancies particularly multi-focal squamous cell carcinoma of the oral mucosa. It acts with similar principle like PAD, generating reactive oxygen species, which in turn, directly damage the cells and the associated blood vascular network, resulting in both necrosis and apoptosis. Thereby the host's immune response is activated and promotes anti-tumor immunity through the activation of macrophages and T lymphocytes. There is also direct evidence of the photodynamic activation of production of the tumor necrosis factor-α which is a key cytokine in host anti-tumor immune responses. Clinical studies have reported results for the PDT treatment in carcinoma in-situ and squamous cell carcinoma, of oral cavity, with approximately 90% response rates.

5.1.4 Aesthetic gingival re-contouring and crown lengthening

Advent of the diode lasers made clinicians choose them to include optimization of gingival aesthetics as part of the comprehensive orthodontic treatment, instead of conventional gingivectomy which is associated with pain, discomfort, and bleeding.

5.1.5 Post herpetic neuralgia and apthous ulcer

Photostimulation of aphthous ulcers and recurrent herpetic lesions have shown to provide pain relief and accelerated healing with low levels of laser energy (HeNe). In recurrent herpes labialis, photostimulation during the prodromal (tingling) stage have shown to arrest the lesions before vesicles formation, accelerate the overall healing time and decrease the frequency of recurrence.

5.1.6 Removal of inflamed, hypertrophic tissue

The diode laser is very useful for a number of isolated applications such as removing tissue that has overgrown mini-screws, springs and appliances. It can also be used as a replacement for tissue punch when placing mini-screws in the gingiva.

5.1.7 Frenectomies

Laser assisted frenectomy could be the best performed procedure after the diastema is closed. Lasers permit excision of the frenum painlessly, without bleeding or suture and there is no need for postoperative care.

5.1.8 Exposure of unerupted and partially erupted teeth

Using lasers an impacted or partially erupted tooth can be exposed allowing for reasonable positioning of a bracket. It gives advantage in the way that the attachment can be placed immediately with no bleeding and pain at all.

5.2 Hard tissue applications [16]

5.2.1 Laser fluorescence

Orthodontic treatment with fixed appliances have enamel demineralization with white spot formation on the buccal surfaces of the teeth as a relatively common side effect. However, there is evidence that such small areas of superficial enamel demineralization may be re-mineralized using lasers.

5.2.2 Photochemical effects

The argon laser can initiate photopolymerization of light-cure restorative materials, which use camphoroquinone as the photo-initiator. The radiation of these argon lasers is also able to alter the surface chemistry of enamel and root surface dentine, permitting the

the reduction in probability of recurrent caries. Argon and Potassium Titanyl Phosphate lasers can achieve good results in cases that are completely unresponsive to conventional photothermal 'power' bleaching.

5.2.3 Treatment of dentinal hypersensitivity

Er: YAG laser have shown to close dentinal tubules near cervical region of tooth more effectively compared to other desensitizing agents. The effect shown has lasted for a comparatively longer period of time.

5.2.4 Cavity preparation, caries, and restorative removal

Er: YAG laser can be used for removing caries in the enamel and dentine by ablation. This procedure can be achieved without rise in temperature on the pulp, and even without water-cooling. The Er: YAG laser is capable of removing few restorative materials like cement, glass ionomer and composite resin.

5.2.5 Etching

Laser etching (Er, Cr: YSGG) can be used as an alternative to acid etching of enamel and dentine. Enamel and dentine surfaces etched with lasers show micro-irregularities with no smear layer formation.

Various types of lasers used for different dental procedures are described in the table 1.

6. Safety

Safe and effective operation of lasers require certain precautions. The laser should be in good working order, with all manufacturer safeguards in place. First and foremost is protective eyewear. Eyewear should have worn by everyone in the vicinity of the laser, while it is in use. They may include the doctor, chairside assistants, patient or any observers such as family or friends. It is very critical that eyewear worn is wavelength-specific. Accidental exposure to the non-target tissue can be prevented by the use of warning signs posted outside the nominal hazard zone and by limiting access to the surgical environment. The number of reflective surfaces should be minimized. In order to prevent possible exposure to infectious pathogens, apart from following normal infection protocols, a high-volume suction should be used to evacuate any vapor plume created during tissue ablation. Each office should have a designated Laser Safety Officer who should regularly supervise the proper use of the laser, coordinate staff training, oversee the use of protective eyewear, and should be familiar with the pertinent regulations.

Dental procedure	**Possible types of lasers**
Laser Doppler flowmetry	*He Ne, diodes*
Laser fluorescence	*He Ne, diodes*
Photodynamic therapy to release fibrotic bands in osmf	*ErCr: YSGG*
Frictional keratosis, leukoplakia, verrucous carcinoma	*Diode*
Hemostasis	*Co_2*
Tuberosity reduction, alveloplasty, bone and flap removal	*Erbium*
Dentine hypersensitivity	*Er:YAG*
Cavity preparation	*Diode*
Composite curing	*Co_2, Nd:YAG, Er:YAG*
Removal of defective composite restoration	*Argon, Er:YAG*
Root canal treatment, apicoectomy	*Co_2, Nd:YAG*
Laser assisted curettage	*Nd:YAG, diode*
Gingivectomy and gingivo plasty	*Co_2*
Analgesic effect and bio- stimulation of wound healing	*He Ne, diode, Nd: YAG*

Table 1. Types of lasers for different dental procedures [17]

7. Limitations

1. Additional training and education are required for various clinical applications of lasers.
2. Cost of equipment is high.
3. Various procedures require different wavelengths thereby increasing the need for more than one type of laser.

8. Conclusion

Lasers have acquired a specialized place in all disciplines of dentistry making it an AMAZING SPECTRUM OF LIGHT. Many types of lasers are available for various clinical purposes. They are activated at different power setting modes, and pulse for soft and hard tissues. Greater numbers of dentists are now using this technology to provide precision treatment to the patients as the applications of the same are being increasing day by day. In the emerging future laser technology, might become an essential component in contemporary dental practice.

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