Lasers and its Clinical Applications in Dentistry
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Abstract
On the spectrum of light, the introduction of Lasers has revolutionized the technology. It has been well utilized in war and peace. Advancement in the medical use for surgery has helped clinicians to overcome several complications and patients’ discomfort. Similarly, since its approval for the medical use, lasers have acquired specialized place in all disciplines of dentistry. Many types of lasers are available for clinical and specific use. They are activated at different power setting modes, and pulse for soft and hard tissues. This review discusses the applications in periodontics, implantology, maxillo-facial surgery and endodontics.

Key Words: Lasers; Infra-red; Pulsed; Sapphire; Healing

Laser is an acronym for Light Amplification by Stimulated Emission of Radiation. Based on Albert Einstein’s theory of spontaneous and stimulated emission of radiation, Maiman developed the first laser prototype in 1960, (1) using a crystal of ruby as a medium that emitted a coherent radiation light, when stimulated by energy. In 1961, the first gas and continuously operating laser was described by Javan et al.(2) Ophthalmologists began using the ruby laser in the early 1960s and now the CO2 and the Nd: YAG (neodymium-doped yttrium aluminum garnet), Er, Cr:YSGG, Diode and Er:YAG lasers are established and most commonly used laser for the surgical procedures. Laser is a type of electromagnetic wave generator.(3) The emitted laser has three characteristic features.
1. Monochromatic: in which all waves have the same frequency and energy.
2. Coherent: all waves are in a certain phase and are related to each other, both in speed and time.
3. Collimated: all the emitted waves are nearly parallel and the beam divergence is very low.(4)

The wave differs in strength (which is amplitude of the swing frequency i.e. the number of times they vibrate, and length which is distance between their crest. The main differentiating characteristic of laser is wavelength, which depends on the laser medium and the excitation mode, for instance continuous wave or pulse mode. Different wave lengths can be classified into three groups:
1. The UV range (ultra-spectrum approximately 400-700 nm).
2. The VIS range (visible spectrum approximately 400-700 nm).
3. The IR range (infra-red spectrum which is approximately 700 nm) to the microwave spectrum. (4)

Lasers are heat producing devices converting electromagnetic energy into thermal energy. The characteristic of a laser depends on its wave-length (WL), and wave-length affects both the clinical applications and design of laser. The WL used in medicine and dentistry generally range from 193 nm to 10600 nm, representing a broad spectrum from ultra-violet to the far infra-red range. The earlier lasers most used in dentistry, the CO2, and Nd:YAG. Since the beam of both lasers fall in the far infra-red range on the spectrum, they are not visible, therefore these lasers often use Quartz fiber incorporating a 630 nm coaxial helium-neon laser into the device to act as an aiming beam and facilitate use.

Classification of Lasers: Lasers can be classified according its spectrum of light, material used, and hardness etc (Table 2). Lasers are also classified as soft lasers and hard lasers.

Soft lasers are of cold (athermic) energy emitted as wavelengths; those are thought to stimulate cellular activity. These soft lasers generally utilize diodes and the manufacturers claim that these lasers can aid healing of the tissue, reduces inflammation, edema, and pain. Clinical application includes healing of localized osteitis, healing of aphthous ulcers, reduction of pain, and treatment of gingivitis. The current soft lasers in clinical use are the:
- Helium-neon (He-N) at 632.8 nm (red, visible).
- Gallium- arsenide (Ga-As) at 830 nm (infra-red, invisible).

Hard lasers (surgical) can cut both soft and hard tissues. Newer variety can transmit their energy via a flexible fiber optic cable. Presently more common type clinically used, under this category the medical lasers are:
- Argon lasers (Ar) at 488 to 514 nm
- Carbon-dioxide lasers (CO2) at 10.6 micro-meter
- Neodymium-doped yttrium aluminum garnet (Nd:YAG) at 1.064 micrometer.
- Holmiumyttrium-aluminum-garnet (Ho:YAG) at 2.1 micro-meter.
- Erbium,chromiummyttrium-slenium-gallium-garnet (Er,Cr:YSGG) at 2.78 micro-meter.
- Neodymiumyttrium-aluminum-perovskite (Nd:YAP) at 1,340 nm.
Temperature and pressure leads to cellular rupture, CO2 lasers causes rapid rise in the intra-cellular penetration depth is approximately 0.2 to 0.3 mm. One of the limitations of this laser is the penetration absorbed at the tissue surface with little scatter or about 98% of energy is converted to heat and mucosa, which has more than 75 to 90% water area. This means they are highly absorbed in oral tissues are wet CO2 laser are absorbed into the for wet tissue regardless of tissue color. As long as specific properties and CO2 laser has an affinity Action on soft tissues:

Regardless of the delivery method used, all CO2 laser light used, this all making for difficult and cumbersome intra-oral access. CO2 laser has been utilized for soft tissue surgery including the oral tissues, since the early 1970s, (7-10) and received safety clearance by the Food and Drug Administration (FDA) for this purpose in 1976.

With the development of hollow wave guide technology, CO2 laser access in the mouth is no longer a problem. These flexible tubes have small diameter, a very short focal distance and a tiny hand piece allowing all around used. Regardless of the delivery method used, all CO2 lasers works in non-contact mode.

Action on soft tissues: All lasers have specific properties and CO2 laser has an affinity for wet tissue regardless of tissue color. As long as tissues are wet CO2 laser are absorbed into the area. This means they are high absorbed in oral mucosa, which has more than 75 to 90% water about 98% of energy is converted to heat and absorbed at the tissue surface with little scatter or penetration.

One of the limitation of this laser is the penetration depth is approximately 0.2 to 0.3 mm. CO2 lasers causes rapid rise in the intra-cellular temperature and pressure leads to cellular rupture, as well as release of vapor and cellular debris, called the “laser Plume”.

The debris arising in the site of impact, the char is carbonized tissue and its accumulation may cause rapid jump in the temperature to 1500 to 2000 degree Celsius, causing extensive thermal damage. Using a focused beam close to the focal point the spot size will be 0.1 to 1.0 mm. divergence of the beam beyond the focal point causes rapid loss of power density and protects the underlying tissue, causing protein coagulation and denaturation.

With the diameter up to 0.5 mm blood vessels in the surrounding tissue can be sealed.(11,12) Gopin et al. used animal models and have observed root charring in cases of mucoperiosteal flap surgery.(13) Heat induced cracking of the root surface is a common observation when using CO2 laser, particularly power setting is > 4 W delivered in a continuous waveform. CO2 used in a low power and pulsed waveform inflicts little damage.(14-15) These studies suggest that CO2 lasers have limited application in subgingival periodontal therapy.

Nd:YAG laser was first developed by Geusic in 1964. A crystal of yttrium-aluminum-garnet doped with neodymium is used and they are invisible similar to CO2 laser, have infra-red range on spectrum, with maximum power output 3W at a frequency of 1.06 micron. This laser has pulse duration of only one sixth-thousand of a second. The light beam is transmitted along extremely flexible fiber optic cables ranging in size from 200 to 600 microns. This allows access to parts of the oral cavity including root canals.(10) This laser is used with a guiding beam helium-neon and contact mode allowing tactic feedback. The depth of penetration has been estimated to be 2 + _ 1 mm in soft tissue.(12)

Each pulse of energy removes 5-10 microns of tissue, depending on the power delivered. The temperature developed at the operating tip is 600 to 2000°C; this renders all soft tissue procedures potentially sterile. The sapphire and ceramic tips have allowed contact and precise delivery at low watt; settings (3 to 20 watts) and high power density using a small (0.2 to 1.2 mm) diameter tip. Absorbance of hemoglobin is nearly
80 percent, therefore for most techniques; a relatively bloodless field can be accomplished. In May, 1990, the US Food Drug Administration permitted the commercial production of pulsed Nd:YAG laser for soft tissue removal.

Erbium:YAG laser: In 1997 with FDA safety clearance erbium: YAG laser have been practiced on hard tissue like enamel, cementum, bone. Er:YAG laser has not been extensively used for the soft tissue applications.

Er:YAG laser has a wavelength of 2,940 nm, which is said to be ideal for absorption by hydroxyapatite crystals and water, making it more efficient in ablating enamel, and dentine. This wavelength causes water to evaporate into steam, being irradiated resulting micro-explosion of the hard tissue.(16) The energy produced at this wavelength is absorbed by water and thus minimum rise in temperature, which is not related to thermal effect on the tissue. Helium neon laser is utilized as aiming beam in the fiber optic delivery system. Water spray is used to wet the surface during laser radiation to achieve maximum efficiency of tissue removal with minimum heat generation. The surface left is like acid etched, which enhances the bond strength to restorations. Minimum heat damage has been reported when used on dental hard tissue at appropriate power densities.(16)

Er:Cr:YSGG laser (Erbium: Chromium: YSGG) also known as water-laser (marketed as Bio-laser in the USA), works by Hydro-kinetic tissue cutting system using laser power to energize water for the use on hard and soft tissues. Water energy in motion can be easily observed, on the rocks erosion caused by oceans water moving, mining of precious metals using high pressure hoses and water, removing debris from the side of the wall etc.

The laser energy excites the fiber and encounters a mist of water droplets which absorbs energy. These droplets are instantly reduced to particulates and propelled with such force that they are capable to cut hydroxyl-apatite crystals of enamel and the osseous skeleton of the bone. The energized water removes hard tissue with great efficiency.

When sapphire tip is in contact the energy is in focus and will cut faster, and when out of touch, defocused the cutting will be slower. This is a pulsed laser works on power range from 0-6 W with wavelength 2.78 microns. The laser energy is delivered through a flexible fiber optic system. Er:Cr:YSGG, lasers are used for the soft tissue and hard tissue, is enjoying great popularity among US dentists.

Diode laser : Indium-gallium-arsenide-phosphide-InGaAsP (diode); Gallium-aluminum-arsenide-GaAlAs (diode); Gallium-arsenide -GaAs(diode). These three kinds of diodes are marketed for use in dentistry now in days. For dental use diode laser has been introduced for last few years after FDA safety clearance. It has wavelength range of 635 to 950 nm, utilizing flexible quartz fiber; it is absorbed by pigmentation of the soft tissue. Thereby making diode laser an excellent hemostatic agent.

Diode is used for soft tissue removal in contact mode, giving tactile sensation similar to electro cautery. The power output used is generally 2 to 10 W, and can be either pulsed or continuous mode. Its effect on the tissue is similar to Nd:YAG laser, with less thermal effects on the deeper tissues.(17) Tissue penetration is less than comparable Nd:YAG effects, with potential for heat damage to underlying bone reduction.(16, 18)

With introduction of laser in the field of dentistry for last several years, it has emerged and witnessed several wonderful experiences by clinicians and the patients. Of all lasers used, oral use CO2 laser is fastest in removing tissue as suggested by several reports, but clinical use of other handy lasers like diode, Er,Cr:YSGG have proved equally better utilization with excellent tissue response.

References


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