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LASERS IN DENTISTRY:A BIRD'S EYEVIEW

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ABSTRACT

During the last decade that lasers have shown rapid strides in technology advances. The emergence of lasers with variable wavelengths and the ability to be used for various applications in dentistry have influenced the treatment of dental patients. It has become mandatory for practicing dentists to update themselves on lasers use in dentistry. This review is an attempt to serve the same purpose.

KEYWORDS: Dental application, lasers, photostimulation

INTRODUCTION

The term LASER is an abbreviation for light amplification by stimulated emission of radiation.[1] External energy induces transition of electrons in the atoms causing the electrons to move from their lower state to an activated state due to the absorption of energy by the electrons of the atom called "stimulated absorption." The lowest energy state being stable, the activated electrons returns to their normal state by spontaneously emitting the extra energy called "spontaneous emission." Instead of spontaneous emission, the electrons of an atom can be stimulated to release energy with a quantum of electromagnetic energy at same transition frequency called as stimulated emission. During this process, it releases an extra photon, which hits against the adjacent activated atom setting off a chain reaction of releasing photons.[2] These released photons are coherent in nature. Lasers are named based on the active medium that is stimulated to produce these waves. The active medium can be a gas, liquid, solid or a semiconductor (diode lasers). The active mediums contain atoms whose electrons may be excited to a metastable energy level. The active medium may be excited using light or electricity. The lasers are monochromatic, unidirectional and coherent. These lasers may be delivered as a continuous, gated-pulse or free running pulse wave.[3]

Laser is a type of electromagnetic wave generator. The emitted laser has three characteristic features –

- Monochromatic : in which all waves have the same frequency and energy.
- Coherent: all waves are in certain phase and are related to each other, both in speed and time.

Collimated: all the emitted waves are nearly parallel and the beam divergence is very low.

HISTORY OF LASERS

n 1960, Theodore Maiman was the first scientist who demonstrated the laser function and also developed a working laser device "known as ruby laser," made of aluminum oxide, that emitted a deep red-colored beam. In 1965, Stern and Sognnaes reported that a ruby laser could vaporize enamel and had thermal effects on the dental pulp. In 1970's, researchers began to find the clinical oral soft tissue uses of medical CO_2 and neodymium- doped:yttrium aluminum garnet (Nd:YAG) lasers. The first laser that had truly both hard and soft tissue application was the CO_2 laser, invented by Patel in 1964.[4] The Nd:YAG laser was also developed in 1964 by Geusic, a year after the invention of ruby laser, but it was largely overshadowed for a long time by the ruby and other lasers of the era until 1990, when the first pulsed Nd:YAG laser was released which is thought to have a better interaction with dental hard tissues.In 1971, The first use of lasers in endodontics was reported by Weichman and Johnson, as they utilize high power infrared CO_2 laser to seal the apical foramen in vitro.[5] Research continues for future indications with an all-tissue laser, including crown and veneer preparations, orthodontic applications, advanced new implant therapies including sinus augmentation and bone grafting, a gingival tissue resurfacing and even low-level laser therapy applications using the yttrium- scandium-gallium-garnet (YSGG) laser.

CLASSIFICATION OF LASERS

1. Gas lasers:

   Argon

   Carbon-dioxide

2. Liquid laser:

   Dyes

3. Solid:

   Nd:YAG

   Erbium: yttrium aluminum garnet (Er: YAG)

   Diode

4. Semiconductor:

   Hybrid silicon laser

5. Excimers:

   Argon-fluoride

   Krypton-fluoride

   Xenon-fluoride

LASER TISSUE INTERACTION

Laser light has four types of interactions with the target tissue which depends on the optical properties of that tissue: Absorption, transmission of laser energy, reflection, scattering of the laser light.

1. Absorption : When the laser is applied to the tissue, there is the absorption of laser energy in the target tissue. Different laser wavelengths have different absorption coefficients with the dental tissue components such as water, pigment, blood contents and mineral. Laser energy can be absorbed or transmitted based on the composition of target tissue. Those primary components are termed chromophores, which can absorb the laser light of specific wavelength. In general, the longer wavelengths, such as erbium laser has a greater affinity with water and hydroxyapatite. CO_2 laser having wavelength of 10,600 nm is well absorbed by water and penetrates only to a few microns of the target tissue's surface.[6] The shorter wavelengths ranging from 500 to 1000 nm are readily absorbed by the pigmented tissue and blood elements. For e.g., The pigment hemoglobin has greater affinity for argon laser while melanin absorbs diode and Nd:YAG laser.The primary determinant, which decides the depth of penetration and absorption of laser light in the target tissue, is the wavelength of the laser used. Depending on the wavelength used, some lasers able to penetrate the tissue deeper than others. In contrast, other laser has a limited penetration and has effect only on the tissue surface. For example, the Nd:YAG which is indicated for bone and hard tissue applications, penetrates 2-5 mm into tissue while CO_2 laser has a limited penetration up to 0.03 to 0.1 mm in the tissue, thus indicated for soft tissue applications. This wavelength provides enough depth to seal the damaged blood, lymphatic vessels and nerve endings resulting in good hemostasis and minimal post-operative morbidity.
2. Transmission: This property depends on the wavelength of laser light used. There is the transmission of the laser energy directly through the tissue without producing any effect on the target tissue. Nd:YAG, Argon and diode laser light gets transmitted through water, whereas tissue fluids readily absorb the erbium family and CO_2 at the outer surface so there is little energy transmitted to adjacent tissues.[6]
3. Reflection : This property of laser causes laser light to redirects itself off the surface, having no effect on the target tissue. This reflected light could be dangerous when redirected to an unintended target such as eyes. However, a caries- detecting laser device uses the reflected light to measure the degree of sound tooth structure.
4. Scattering of the Laser Light There is also scattering of the laser light with correspondence decrease of that energy and possibly producing no useful biologic effect. This property can cause unwanted damage as there is heat transfer to the tissue adjacent to the surgical site. However, a beam deflected in different directions facilitates the curing of the composite resin or when treating an aphthous ulcer. The clinician must be aware of certain factors before applications of lasers such as appropriate laser wavelength, beam diameter, focused or defocused mode, pulse energy or power output, spot size, and tissue cooling. The result of using the

smaller spot greatly increases the heat transfer from the laser to the tissue and a corresponding increased heat absorption in that smaller area. If the laser beam is allowed to diverged from the target tissue, this would results in the increase of the beam diameter and thus lessen the energy density of the laser beam. If a laser beam is allowed to strike the target tissue for a longer time, it will cause the tissue temperature to rise. This time can be regulated by the repetition rate of the pulsed laser emission mode as well.

LASER WAVELENGTH USED IN DENTISTRY

1. Argon laser : This laser has an active medium of ionized argon gas, energized by a high current electrical discharge, and the laser light is delivered fiber-optically in continuous wave and gated pulsed modes. There are two emission argon laser wavelengths used in dentistry: 488 nm (blue) and 514 nm (blue green). Both wavelengths are poorly absorbed in the enamel and dentin which is advantageous during cutting and sculpting gingival tissues as there is minimal interaction with the dental hard tissue without causing any damage to the tooth surface. Both wavelength is 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 and is easily discernible from the surrounding healthy structures. Argon lasers are indicated in periodontics, as they possess bactericidal properties against Prevotella intermedia and Porphyromonas gingivalis and also used to treat vascular malformations such as a hemangioma. Potential complications of this laser treatment include granuloma formation, bleeding or non-resolution of the lesion.[7-8]
2. Diode lasers: The diode laser is manufactured from solid semiconductor crystals made from a combination of aluminum (with wavelength of 800 nm) or indium (900 nm), gallium and arsenic. These wavelengths penetrate deep into the mucosa and highly attenuated by the pigmented tissue, although hemostasis is slow as compared with the argon laser. These lasers are excellent soft tissue surgical lasers so surgery can be performed safely as these wavelengths are poorly absorbed by the dental hard tissue. This laser is indicated for gingivoplasty, sulcular debridement and deeper coagulation process on gingival and mucosa. The chief advantage of the diode lasers is one of a smaller size, portable instrument. These lasers can also stimulate fibroblastic proliferation at low energy levels.[8-9]
3. Nd-YAG Lasers : Nd:YAG has a solid active medium, which is a garnet crystal combined with rare earth elements yttrium and aluminum, doped with neodymium ions. The available dental wavelength of 1064 nm is indicated for various soft-tissue procedures such as cutting and coagulating of gingival and sulcular debridement. This laser provides good hemostasis provides a clear operating field during soft-tissue procedures. The laser is also indicated for the removal of incipient caries, although the working efficiency is less in comparison with the Er: YAG, or Er, chromium (Cr):YSGG lasers. When used in a noncontact, defocused mode, this wavelength can penetrate several millimeters which can be used for procedures such as treatment of aphthous ulcers or pulpal analgesia. However, due to a decrease in pulpal function, sometimes damage to the dental pulp can results.[10]
4. Erbium, Cr:YSGG (2780 nm) Erbium, Cr: YSGG (2780 nm) which has an active medium of a solid crystal of yttrium scandium gallium garnet doped with erbium and chromium.
5. Erbium:YAG (2940 nm) Erbium: YAG (2940 nm) which has an active medium of a solid crystal of yttrium aluminum garnet doped with erbium. Both lasers aid in caries removal. The laser produces clean, sharp margins during cavity preparation. Since, depth of penetration of laser wavelength is less, so pulpal damage is minimal. During caries removal, since the laser has an anesthetic effect, the analgesia is not routinely indicated in the majority of patients. The laser also assists in removal of endotoxins from root surfaces so providing an anti-microbial effect. These lasers are comfortable to the patients as vibration produces from the laser are less severe in comparison to the conventional high-speed drill. Thus, they are less likely to provoke intraoperative discomfort or pain.[11-12]

6. The Er-Cr:YSGG Laser : This laser is widely indicated in restorative and etching procedures. During cavity preparation, the laser provides rough surfaces for bonding without causing any significant cracking in the dental hard tissue. The advantage of this laser for restorative dentistry is that a carious lesion in close proximity to the gingiva can be treated and the soft tissue recontoured with the same instrumentation. Furthermore, tissue retraction for uncovering implants is safe with this wavelength, because there is minimal heat transferred during the procedure. However, the rough surface produced during etching procedures will have a wide range of strengths of enamel bonds which is unreliable. Therefore, the procedure still requires acid etching to obtain equivalent bond strength.[12]
7. CO_2 Laser : The CO_2 laser is water or air cooled gas discharge, containing a gaseous mixture with CO2 molecules, that helps in producing a beam of infrared light. The light energy, whose wavelength is 10,600 nm, well absorbed by water and is delivered through a hollow tube-like waveguide in continuous or gated pulsed mode. The laser wavelength can easily assists in cutting and coagulation of soft tissue, thus providing a clear operating field. The laser is indicated for the treatment of mucosal lesion, since it has a limited penetration depth. Post-operative pain usually is minimal to none as it reduced pain by inducing local neural anesthesia as a function of neuron sealing and decreased pain mediator release. CO_2 laser also has some disadvantages. However, there is delayed wound healing for a few days, as a result of delayed re-epithelization and a different pattern of wound contraction. Furthermore, the loss of tactile sensation could pose a disadvantage for the surgeon, but the tissue ablation can be precise with careful technique.[13-14]

USES OF LASER ON HARD TISSUE

1. Laser Assisted Caries Diagnosis and Management : The Diagnodent caries detection laser is a portable, battery powered diode laser. Its 655 nm visible wavelength causes active caries to fluoresce. The amount of fluorescence is measurable and is correlated to the size and direction of the lesion. When combined with Caries Management by Risk Assessment (CAMBRA) it can be a very useful tool for detecting and managing early caries. The laser gives a reading of zero to 99. A general guideline is that occlusal lesions above 30 likely need restoration and those from ten to 30 are potentially reversible. The Diagnodent can be an excellent tool for measuring the effectiveness of non-surgical interventions such as increased fluoride exposure, dietary changes, and the like. It also is excellent at detecting "hidden caries" in pits and fissures. Occlusal lesions in a fluoridated population can often be quite advanced before cavitation can be detected with an explorer. Laser diagnosis can help solve this vexing problem for the modern dentist when aired with CAMBRA and high magnification visualization. The Diagnodent's primary indication is for detecting class I, class V, and incisal caries. It can also be useful when paired with transillumination for detecting permanent class III and primary class 2 lesions. Experienced clinicians have found they can greatly reduce the need for radiographs to detect these particular lesions. Laser caries detection can also be used intraoperatively to check minimally restorative preparations for complete decay removal. The Diagnodent's primary indication is for detecting class I, class V, and incisal caries. It can also be useful when paired with transillumination for detecting permanent class III and primary class II lesions. Experienced clinicians have found they can greatly reduce the need for radiographs to detect these particular lesions. Laser caries detection can also be used intraoperatively to check minimally restorative preparations for complete decay removal.[18-20]
2. Restorative Dentistry : Er:YAG and Er,Cr:YSGG machines are multi tissue lasers that are FDA approved for cutting tooth, bone and soft tissue. Their extremely short pulses and high peak power allow for efficient enamel and dentin photoacoustic ablation. Erbium lasers can prepare all classes of restorations. Many restorations can be accomplished without local anesthesia. Experienced laser practitioners report needing anesthesia only ten to 20% of the time, usually for amalgam removal,

very large lesions, or particularly sensitive teeth. Advantages of using erbium laser for operative dentistry include: - Precise ablation allows for minimally invasive preparations ,Smear layer removal, Disinfection of preparations , Eliminates the noise, heat, and vibration of high speed rotary instrumentation , Reduced need for local anesthesia , Selective caries removal due to carious dentin's higher water content and softer consistency.[21-22]

3. Surgical Applications of Dental Lasers : All four major wavelengths of dental lasers are excellent soft tissue surgical devices. The primary chromophores for diode and Nd:YAG lasers are pigments such as hemoglobin and melanin. The erbium and CO2 lasers are mostly absorbed by water. All these lasers use photothermal effects to incise tissue whereby photons absorbed are converted to heat energy in order to do work. Diode and Nd:YAG lasers exhibit much deeper tissue penetration and thermal effects than the erbium lasers and the potential for tissue damage is greater. As such, proper training and an understanding of the biological effects of lasers are imperative for any provider wanting to pursue laser dentistry. Thermal relaxation varies depending on the laser and parameters employed. Erbium lasers exhibit the greatest thermal relaxation due to their short free running pulses and minimal tissue penetration. Histological examination of erbium incised tissue exhibits almost no tissue damage or inflammatory response. Nd:YAG lasers also run on free running pulsed mode with pulse durations as short as 100 microseconds. However, due to their high absorption by pigment and deeper penetration they exhibit significantly greater heating of tissue and this factor needs to be respected by the practitioner. Diodes and CO_2 lasers run in continuous or gated wave mode so they have much less thermal relaxation capabilities. Recent technological advances in so called "superpulsed modes" have helped improve the thermal parameters of these lasers, but it is important to note this is not a true free running pulsed mode. In addition, diodes have the potential for greater thermal effects than CO_2 due to their differing chromophores and depth of penetration. Er:YAG and Er,Cr:YSGG lasers are also capable of cutting bone and have FDA clearance for osseous use. Multiple studies have shown erbium irradiated bone shows minimal thermal damage, necrosis, or inflammation. Clinically this relatively atraumatic cutting of bone results in rapid and comfortable healing observed by laser practitioners. Erbium and CO_2 lasers have been shown to effectively decontaminate implant surface without damaging titanium and are useful in treating peri-implantitis. [23]

LASER SAFETY

Laser Safety Proper safety procedures must be put in place by any practice implementing laser use. A laser safety officer needs to be appointed by the clinic whose job it is to implement and monitor safety protocols. The manufacturer of each device is obliged to train the providers the important safeguards needed for each device. Common safety practices include:

- Eye Protection – The patient, clinical staff and any observers must wear protective eyewear specific for the wavelength being used.
- Plume Control – Laser procedures create a plume that may contain hazardous chemicals and microflora. Standard dental high-speed evacuation properly used is adequate to control the plume. Good quality masks need to be worn by the clinicians.
- Sharps – Scored laser tips of quartz fibers are considered sharps and need to be disposed of as such.
- Warning Sign – Warning signs need to be in a visible place and access to the operatory limited.

Adequate precautions to prevent injury or damage to adjacent soft and hard tissue or to the pulp and periodontal apparatus. According to Zach and Cohen, 30 an intra-pulpal temperature increase of approximately 5.5°C can promote necrosis and a temperature increase of 7°C is considered as the highest thermal change biologically acceptable to avoid periodontal damage.[24-26]

CONCLUSION

There is a learning curve in the use of lasers in dentistry. As long as the clinician has completed a training course & proceeds through the learning curve at a comfortable pace, the rewards will quickly be noticed by the patient and the dental team. Lasers can prove to be a blessing in disguise if used safely and properly.

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