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Lasers in Dentistry

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Abstract
The introduction of Lasers has revolutionized the technology in the field of light. It has seen action in both war and peace. Clinicians have been able to overcome several complications and patients' discomfort thanks to advancements in medical use for surgery. Lasers, too, have gained a specialized place in all disciplines of dentistry since their approval for medical use. Lasers were introduced into the field of clinical dentistry in the hopes of alleviating some of the disadvantages associated with traditional dental procedures. Since its first experiment in the 1960s for dental applications, the use of laser has exploded in the last two decades. Different types of lasers are available for clinical and specific use due to their many advantages. They work in a variety of power settings and pulse for soft and hard tissues.

Keywords: *Lasers, soft tissue laser, hard tissue laser, Er:YAG, Waterlase*

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I. Introduction

Dentistry has changed tremendously over the past decade to the benefit of both the clinician and the patient. One technology that has become increasingly utilized in clinical dentistry is that of the laser. Laser is an acronym for Light Amplification by Stimulated Emission of Radiation.[1] Lasers have become widely used in medicine and surgery since the development of the ruby laser by Maiman in 1960.[2] Lasers designed for surgery deliver concentrated and controllable energy to tissue. For a laser to have biological effect, the energy must be absorbed. The degree of absorption in tissue will vary as a function of the wavelength and optical characteristics of the target tissue. Initially introduced as an alternative to the traditional halogen curing light, the laser now has become the instrument of choice, in many applications, for both periodontal and restorative care. Because of their many advantages, lasers are indicated for a wide variety of procedures. Presently various laser systems have been used in dentistry. Among them Carbon dioxide (CO2), Neodymium-doped: Yttrium-Garnet (Nd:YAG), Semiconductor diode lasers are used for soft tissue treatment. Recently Erbium doped: Yttrium-Aluminium Garnet (Er:YAG) laser has been used for calculus removal and decontamination of the diseased root surface in periodontal non-surgical, surgical and implant therapy.[3] Certain laser wavelengths (i.e. Er: YAG, Er,Cr: YSGG) are highly absorbed by hydroxyapatite and can be used for bone removal more efficiently than others. In contrast, diode and Nd: YAG lasers are more highly absorbed by hemoglobin and thus should be used when coagulation is desirable. In addition, due to the effect that these wavelengths (diode and Nd: YAG lasers) have on pigmented tissues, they can be used by periodontists for removal of gingival pigmentation and/or reduction of periodonto-pathogenic black-pigmented bacteria.

DEFINITION

The word “laser” is an acronym for “light amplification by stimulated emission of radiation.” It refers to a device that emits light that is spatially coherent and collimated; a laser beam can remain narrow over a long distance, and it can be tightly focused. When directed at tissues, different interactions result. The absorption, reflection, transmission, and scattering of the laser light vary depending on the wavelength of the laser and the characteristics of the tissue.[2]

CLASSIFICATION OF LASERS

Lasers can be classified according to its spectrum of light, material used and hardness etc. They are also classified as soft tissue lasers and hard tissue lasers.

Table 1: Classification based on light spectrum

UV Light	100 nm – 400 nm	Not Used in Dentistry
Visible Light	400 nm – 750 nm	Most commonly used in dentistry (Argon & Diagnodent Laser)
Infrared light	750 nm – 10,000 nm	Most Dental Lasers are in this spectrum

Table 2: Classification According to Material Used

Gas	Liquid	Solid
Carbon Dioxide	Not so far in clinical use	Diodes, Nd:YAG, Er:YAG, Er:Cr:YSGG, Ho:YAG

Soft tissue lasers

Soft tissue 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 tissue lasers in clinical use are:

- Helium-neon (He-N) at 632.8 nm (red, visible).
- Gallium- arsenide (Ga-As) at 830 nm (infra-red, invisible).

Hard tissue lasers (surgical)

Hard lasers 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 hard tissue 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.
- Neodymiummyttrium-aluminum-perovskite (Nd:YAP) at 1,340 nm.

TYPES OF LASERS[4]

On the basis of output energy

- Low output, soft or therapeutic eg. Low-output diodes
- High output, hard, or surgical eg. CO2,Nd:YAG,Er:YAG

On basis of state of gain medium

- Solid- eg.Nd:YAG, Er:YAG, Er,Cr:YAG
- Gas- eg.HeNe, Argon,CO2 o Excimer-eg. ArF, KrCl o Diode- eg. GaAIAs

On the basis of oscillation mode

- Continous wave eg. CO2, Diodes
- Pulsed wave eg. Nd:YAG, Er:YAG

MECHANISM OF ACTION OF LASERS

Laser light is a man-made single photon wavelength. The process of lasing occurs when an excited atom is stimulated to emit a photon before the process occurs spontaneously. Spontaneous emission of a photon by one atom stimulates the release of a subsequent photon and soon. This stimulated emission generates a very coherent (synchronous waves), monochromatic (a single wavelength), and collimated form (parallel rays) of light that is found nowhere else in nature.[5] Laser is a type of electromagnetic wave generator.[6] Lasers are heat producing devices converting electromagnetic energy into thermal energy. 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.[7]

Laser light is produced by pumping (energizing) a certain substance, or gain medium, within a resonating chamber. The gain medium then emits photons, which bounce back and forth between the reflectors. Part of the radiation is allowed to exit through an aperture in one of the reflectors, resulting in the laser beam.[8] The various laser systems are usually named after the ingredients of the gain medium, but three factors are important for the final characteristics of the laser light: composition of the gain medium, source of pump energy, and design of the resonating chamber.[8]

Lasers can interact with their target material by either being absorbed, reflected, transmitted, or scattered.[9] Absorbed light energy gets converted to heat and can lead to warming, coagulation, or excision and incision of the target tissue. Although the wavelength of the laser is the primary determinant of how much energy is absorbed by the target tissue, optical properties of the tissue, such as pigmentation, water content, and mineral

content, can also influence the extent of energy absorbed.[10] The term 'waveform' describes the manner in which laser power is delivered over time, either as a continuous or as a pulsed beam emission. Continuous wave lasers deliver large amounts of energy in an uninterrupted steady stream potentially resulting in increased heat production. Pulsed wave lasers usually deliver smaller amounts of energy in interrupted bursts, thereby countering the build-up of heat in the surrounding tissues.[11] The characteristic of a laser depends on its wave-length (WL), and wave-length affects both the clinical applications and design of laser.
Different wave lengths can be classified into three:
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.

CLINICAL APPLICATIONS OF LASERS IN DENTISTRY

Cavity preparation

The Er: YAG laser was tested for preparing dental hard tissues for the first time in 1988. It was successfully used to prepare holes in enamel and dentine with low 'fluences' (energy (mJ)/unit area (cm2)). Even without water-cooling (Burkes *et al*., 1992), the prepared cavities showed no cracks and low or no charring while the mean temperature rise of the pulp cavity was about 4.3°C (Rechmann *et al*., 1998).[12,13]

Restoration removal

The Er: YAG laser is capable of removing cement, composite resin and glass ionomer (Dostalova *et al*., 1998).[14] The efficiency of ablation is comparable to that of enamel and dentine. Lasers should not be used to ablate amalgam restorations however, because of potential release of mercury vapor. The Er: YAG laser is incapable of removing gold crowns, cast restorations and ceramic materials because of the low absorption of these materials and reflection of the laser light (Keller et al., 1998).[15] These limitations highlight the need for adequate operator training in the use of lasers.

Treatment of dentinal hypersensitivity

Dentinal hypersensitivity is one of the most common complaints in dental clinical practice. Various treatment modalities such as the application of concentrated fluoride to seal the exposed dentinal tubules have been tested to treat the condition. However, the success rate can be greatly improved by the ongoing evaluation of lasers in hard tissue applications. A comparison of the desensitizing effects of an Er: YAG laser with those of a conventional desensitizing system on cervically exposed hypersensitive dentine (Schwarz *et al*., 2002) showed that desensitizing of hypersensitive dentine with an Er: YAG laser is effective, and the maintenance of a positive result is more prolonged than with other agents.[16]

APPLICATION OF LASERS IN PERIODONTOLOGY

The use of lasers in periodontal treatment has been well documented over the past 10 years. Lasers can be used for initial periodontal therapy and surgical procedures. This usage becomes more complicated because the periodontium consists of both hard and soft tissues. Among the many lasers available, high-power lasers such as CO2, Nd:YAG and diode laser can be used in periodontics because of their excellent soft tissue ablation and haemostatic characteristics. However, when they are applied to the root surface or alveolar bone, carbonization and thermal damage have been reported.[17]

Initial periodontal therapy scaling and root planing:

Soft tissue lasers are a good choice in bacterial reduction and coagulation. The erbium group of lasers has shown significant bactericidal effect against porphyromonas gingivalis and actinobacillus actinomycetemcomitans.[18] Reduction of interleukins and pocket depth was noted with laser therapy.

Removal of the pocket epithelium

The Nd: YAG was the first laser wavelength to be compared to the scalpel for treating periodontal pockets and controlling bacteremia and gingival bleeding.[19] The probing pocket depth and bleeding index scores were reduced using the pulsed Nd: YAG laser. Furthermore, clinical evaluation of soft tissue biopsies taken from human subjects using the Nd: YAG laser versus a curette presented a complete removal of the epithelium of the pocket after use of the pulsed Nd: YAG laser compared to the curette.[20]

Reduction of bacteria

A laser application that has been especially promoted in the past is for the reduction of bacteria in pockets, due to the high absorption of specific laser wavelengths by the chromophores. Initially, the use of an Nd: YAG laser was shown to reduce the load of Porphyromonas gingivalis and Prevotella intermedia.[21]When pigmented with melanin or hemoglobin, the blue green visible light of the argon laser is readily absorbed by the oral tissues. Hemangiomas and other pigmented highly vascular lesions respond well to the argon wavelength for removal and cauterization. This property has been used to allow black pigmented bacteria to selectively absorb argon laser energy. The main putative pathogens in the periodontal lesion are gram-negative black pigmented anaerobes.

Table 3: Laser Treatment of Chronic Periodontitis: Longitudinal Clinical Trials and Cohort Studies

Studies	**Type of Laser**	**Number of Patients**	**Length of Study (days**	**Initial PD (mm)**	**Decrease in Subgingival Bacteria: Laser Versus Control**
Radvar *et al.*[22]	Nd:YAG	11	42	>4	At 6 weeks, only the SRP group showed a significant reduction from baseline.
Moritz *et al.*[23]	GaAs diode	50	180	3.9 versus 3.0 (mean depth in molar region)	No significant difference. 59% of lased sites had 1 log decrease versus 33% of controls; 27% of lased sites had 2 log decrease versus 17% of controls.
Schwarz *et al.*[24]	Er:YAG	20	180	$\geq$4	No significant difference between treatment groups
Sculean *et al.*[25]	Er:YAG	23	180	7.8	NA

ADVANTAGES AND DISADVANTAGES OF LASERS

Advantages of laser treatment includes greater hemostasis, bactericidal effect as well as minimal wound contraction. Compared with the use of a conventional scalpel, lasers can cut, ablate and reshape the oral soft tissue more easily, with no or minimal bleeding and little pain as well as no or only a few sutures. The use of lasers also has disadvantages that require precautions to be taken during clinical application.[26]Even in the noncontact mode, laser irradiation can interact with tissues, which means laser beams may reach the patient's eyes and other tissues surrounding the target in the oral cavity. Clinicians must exercise caution to avoid inadvertent irradiation of these tissues, particularly the eyes. The patient, operator, and assistant must all wear protective eyewear that is specific to the wavelength of the laser in use. Laser beams can be reflected by the shiny surfaces of metal dental instruments, causing irradiation of other tissues, which can be avoided by covering the target area with wet gauze packs. Previous laser systems, on the other hand, had significant thermal side effects, causing hard tissue melting, cracking, and carbonization.

RISKS ASSOCIATED WITH CLINICAL USE OF LASERS

1. Excessive tissue destruction by direct ablation and thermal side effects.
2. Destruction of the attachment apparatus at the bottom of pockets.
3. Excessive ablation of root surface and gingival tissue within periodontal pockets.
4. Thermal injury to the root surface, gingival tissue, pulp, and bone tissue.

PRECAUTIONS TO BE TAKEN WHILE USING LASERS

1. Use glasses for eye protection (patient, operator, and assistants).
2. Prevent inadvertent irradiation (action in noncontact mode).
3. Protect the patient’s eyes, throat, and oral tissues outside the target site.
4. Use wet gauze packs to avoid reflection from shiny metal surfaces.
5. Ensure adequate high-speed evacuation to capture the laser plume.

RECENT ADVANCEMENT IN LASERS

The Waterlase system is a revolutionary dental device that uses laser-activated water to cut or ablate soft and hard tissue, allowing periodontists to perform more procedures in fewer appointments while using less anesthesia, scalpels, and drill. Periowave, a photodynamic disinfection system utilizes nontoxic dye (photosensitizer) in combination with low intensity lasers enabling singlet oxygen molecules to destroy bacteria. After applying light-sensitive drug (photosensitizer), low-intensity laser is directed on the area treated with the drug resulting in phototoxic reactions. Although the use of photosensitizers for complete suppression of the anaerobic perio-pathogens have been suggested, however, the same is not true for facultative anaerobes.[27]

II. Conclusion

Laser therapy is expected to be used in conjunction with traditional mechanical periodontal therapy. The benefits of hemostasis, a dry field, shorter surgical times, and less postoperative swelling should all be considered when deciding whether or not to use a laser. One of the most common applications for lasers is soft tissue surgery. Lasers such as CO2, Nd:YAG, Er:YAG, and Er,Cr:YAG are commonly used for these procedures. Periodontics will see the introduction of laser or laser assisted pocket therapy as a new technical modality. Furthermore, its bactericidal effect with lipopolysaccharide elimination, ability to remove bacterial plaque and calculus, irradiation effect limited to an ultra-thin layer of tissue, and faster bone and soft tissue repair make it a promising tool for periodontal treatment, such as scaling and root surface debridement. The benefits of hemostasis, a dry field, shorter surgical times, and less postoperative swelling should all be considered when deciding whether or not to use a laser.

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