Role of lasers in periodontology: A Review

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Abstract

Lasers were introduced into the field of clinical dentistry with the hope of overcoming some of the drawbacks posed by the conventional methods of dental procedures. Since its first experiment for dental application in the 1960s, the use of laser has increased rapidly in the last couple of decades. Because of their many advantages different 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.

Key Words: - Laser, Periodontics, Implant

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] Laser is a device that utilizes the natural oscillations of atoms or molecules between energy levels for generating coherent electromagnetic radiation usually in the ultraviolet, visible, or infrared regions of the spectrum. It is a device that produces high intensity of a single wavelength and can be focused into a small spot. 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. [2]

Review of literature:

In 1917 Einstein published ideas on stimulated emission 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 [4]. The application of a laser to dental tissue was reported by Stern and Sognnaes[5] and Goldman[6] et al. in 1964, describing the effects of ruby laser on enamel and dentine with a disappointing result. Studies on the use of the neodymium-doped yttrium aluminium garnet (Nd:YAG) laser for caries prevention have been published by Yamamoto and Sato[7] and on the use of carbon dioxide (CO2) laser for dental caries treatment by Melcher [8]et al.

The first dental lasers approved by the US Food and Drug Administration, namely the CO2, the Nd:YAG and the diode lasers were accepted for use only for oral soft tissue procedures in periodontics.

In 1997, the Food and Drug Administration cleared the first Er:YAG laser system, then in use for preparing dental cavities, for incisions, excisions, vaporization, ablation and hemostasis of soft and hard tissues in the oral cavity[9].

However, with the recent advances and developments of wide range of laser wavelengths and different delivery systems, researchers suggest that lasers could be applied for the dental treatments including periodontal, restorative and surgical treatments. Currently, numerous laser systems are available 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.

Classification of Lasers:

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

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 – 10000 nm	Most Dental Lasers are in this spectrum

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

1. Soft laser

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).

2. **Hard 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 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[9]

- **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 state-eg.Nd:YAG, Er:YAG, Er,Cr:YAG
  - Gas- eg.HeNe, Argon,CO2
  - Excimer-eg. ArF, KrCl
  - 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:

The physical principle of laser was developed from Einstein's theories in the early 1900s, and the first device was introduced in 1960 by Maiman.[10] Since then, lasers have been used in many different areas in medicine and surgery. 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.[11]

Laser is a type of electromagnetic wave generator[12]. 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.[13]

Lasers can concentrate light energy and exert a strong effect, targeting tissue at an energy level that is much lower than that of natural light. The photon emitted has a specific wavelength that depends on the state of the electron's energy when the photon is released. Two identical atoms with electrons in identical states will release photons with identical wavelengths.

Lasers can interact with their target material by either being absorbed, reflected, transmitted, or scattered [14]. 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.[15]

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.[16] 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.

Advantages and Disadvantages:

Advantages of laser treatment are greater hemostasis, bactericidal effect, and minimal wound contraction [17,18,19]. 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.[20] Laser irradiation can interact with tissues even in the noncontact mode, which means that laser beams may reach the patients eyes and other tissues surrounding the target in the oral cavity. Clinicians should be careful to prevent inadvertent irradiation to these tissues, especially to the eyes. Protective eyewear specific for the wavelength of the laser in use must be worn by the patient, operator, and

assistant. Laser beams can be reflected by shiny surfaces of metal dental instruments, causing irradiation to other tissues, which should be avoided by using wet gauze packs over the area surrounding the target. However, previous laser systems have strong thermal side effects, leading to melting, cracking, and carbonization of hard tissues.

Current and potential applications of Lasers in Dentistry

TYPE	ACTIVE MEDIUM	DENTAL APPLICATIONS
Excimer Lasers	Argon –fluoride(ArF) Xenon-chloride (XeCl)	Hard tissue ablation, dental calculus removal
Gas Lasers	Argon (Ar) Helium-neon (HeNe) Carbon dioxide(CO_2)	• Curing of composite materials, tooth whitening, intraoral soft tissue surgery, sulcular debridement (subgingival curettage in periodontitis and periimplantitis) • Analgesia, treatment of dentin hypersensitivity, apthous ulcer treatment • Intraoral soft tissue and soft tissue surgery, aphthous ulcer treatment, removal of gingival melanin pigmentation, treatment of dentin hypersensitivity, analgesia
Diode Lasers	Indium-gallium-arsenide-phosphorous(InGaAsP) Galium-aluminium-arsenide(GaAlAs) Gallium-arsenide (GaAs)	Caries and calculus detection Intraoral general and implant soft tissue surgery, sulcular debridement (subgingival curettage in periodontitis and periimplantitis), analgesia, treatment of dentin hypersensitivity, pulpotomy, root canal disinfection, apthous ulcer treatment, removal of gingival melanin pigmentation
Solid-state Lasers	Frequency-doubled alexandrite Neodymium:yttrium-aluminium-garnet(Nd:YAG)	Selective ablation of dental plaque and calculus Intraoral soft tissue surgery, sulcular debridement (subgingival curettage in periodontitis), analgesia, treatment of dentin hypersensitivity, pulpotomy, root canal disinfection, removal of enamel caries, aphthous ulcer treatment , removal of gingival melanin pigmentation
	Erbium group Erbium:YAG(Er:YAG) Erbium:yttrium(Er:YSGG) Erbium, chromium:YSGG(Er:YSGG)	Caries removal and cavity preparation, modification of enamel and dentin surfaces, intraoral general and implant soft tissue surgery, sulcular debridement (subgingival curettage in periodontitis and periimplantitis), scalingof root surfaces, osseous surgery, treatment of dentin hypersensitivity, analgesia, pulpotomy, root canal treatment and disinfection, aphthous ulcer treatment, removal of gingival melanin and metal-tattoo-pigmentation

Precautions and Risks Associated with Clinical use of Lasers:[20]

Precautions before and during Irradiation

1. Use glasses for eye protection (patient, operator, and assistants).
2. Prevent inadvertent irradiation (action in non-contact 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.

Potential risks

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.

Applications of Lasers in Periodontal Treatment

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. When used in deep periodontal pockets with associated bony defects, the laser not only removes the diseased granulation tissue and associated bacteria; it also promotes osteoclast and osteoblast activity, often resulting in bone regrowth. This usage becomes more complicated because the periodontium consists of both hard and soft tissues. Among the many lasers available such as CO2, Nd:YAG and diode lasers can be used in periodontics because of their excellent ablation and hemostatic characteristics.

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[21]. Reduction of interleukins and pocket depth was noted with laser therapy.

Soft Tissue Applications:

Laser is effectively used to perform gingivectomies, gingivoplasties, free gingival graft procedures, crown lengthening, operculectomy and many more[22]. Gingival depigmentation using laser ablation has been recognized as an effective, pleasant, and a reliable technique. In terms of aesthetic dentistry, the use of the Erbium laser in crown lengthening in the anterior has created an entirely new dimension in smile design.

LASER ASSISTED NEW ATTACHMENT PROCEDURE (LANAP):

Initial reports suggest that LANAP can be associated with cementum-mediated new connective tissue attachment and apparent periodontal regeneration of diseased root surface in humans.

Osseous Surgery:

As far as osseous applications, the benefit of the Erbium-YAG is the ability to recontour osseous tissue without the discomfort and healing time commonly seen with traditional methods.

Laser And Implant:

Gingival enlargement is relatively common around implants when they are loaded with removable prosthesis. Lasers can be used for the hyperplasia removal as well as in the treatment for peri-implantitis. Er:YAG laser due to its bactericidal and decontamination effect, can be used in the maintenance of implants. It has bacterial effect without heat generation around implants [23].

The use of these lasers is limited to ginivectomy, gingivoplasty, frenectomy, deepithelization of reflected periodontal flap, removal of granulation tissue , second stage exposure of dental implants, coagulation of free gingival graft donor sites and gingival depigmentation and metal tattoos of the gingiva. Some researchers have suggested using the Er:YAG Laser to prepare fixture holes in the bone tissue in order to achieve faster osseointegration of the placed implants and to produce less tissue damage in comparison to conventional bur drilling.

Recent Advances:

Waterlase system is a revolutionary dental device that uses laser energized water to cut or ablate soft and hard tissue. Periowave, a photodynamic disinfection system utilizes nontoxic dye (photosensitizer) in combination with low intensity lasers enabling singlet oxygen molecules to destroy bacteria.[24]

Conclusion:

As technology advances into dentistry, whether it is laser or another exciting venue, the options available to clinicians will continue to increase. Although the use of lasers in dentistry is relatively new, the future looks very bright. In summary, laser treatment is expected to serve as an alternative or adjunctive to conventional mechanical periodontal treatment. Currently, among the different types of lasers available, Er:YAG and Er,Cr:YSGG laser possess characteristics suitable for dental treatment, due to its dual ability to ablate soft and hard tissues with minimal damage. In addition, its bactericidal effect with elimination of lipopolysaccharide, ability to remove bacterial plaque and calculus, irradiation effect limited to an ultra-thin layer of tissue, faster bone and soft tissue repair, make it a promising tool for periodontal treatment including scaling and root surface debridement. The decision to use a laser should be based on the proven benefits of hemostasis, a dry field, reduced surgical time and the general experience of less postoperative swelling.

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