ISSN: 0976-3031

Available Online at http://www.recentscientific.com

International Journal of Recent Scientific Research
Vol. 7, Issue, 6, pp. 11924-11929, June, 2016

International Journal of Recent Scientific Research

Research Article

APPLICATION OF LASERS IN PERIODONTICS: A REVIEW OF THE LITERATURE

Muzafar Ahmad Bhat[1]., Shajah Hussain[2]., Mohamad Imran[3]., ShaistaRehman[4]., Suhail Majid Jan[5] and RoobalBehal[6]

[1]Department of Periodontics, Government Dental College, Srinagar
[2]Department of oral and Maxillofacial Surgery IGDC Jammu
[3]Department of oral and Maxillofacial Surgery SKIMS MC/H Srinagar
[4]BDS, GDC Srinagar
[5,6]Department of Periodontics, Government Dental College, Srinagar

ARTICLE INFO

Article History:

Received 16th March, 2016
Received in revised form 24th April, 2016
Accepted 23rd May, 2016
Published online 28th June, 2016

Key Words:

Laser, Periodontics, Implant.

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 of lasers in periodontics.

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]

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[3] using a crystalof ruby as a medium that emitted a coherent radiation light, when stimulated by energy. In 1961, the first gas andcontinuously 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 *et al*.[8]

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 issue procedures in periodontics.

In 1997, the Food and Drug Administration cleared the firstEr: YAG laser system, then in use for preparing dental cavities, for

Corresponding author:* ***Muzafar Ahmad Bhat*
Department of Periodontics, Government Dental College, Srinagar

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.

Importance of Wavelength

Typically, lasers are named according to the active element(s) that is induced to undergo the stimulated quantum transitions that, in turn, creates the energy beam. Thus, lasers commonly used in dentistry consist of a variety of wavelengths delivered as either acontinuous, pulsed (gated), or running pulse waveform, e.g., CO2, Nd: YAG, Ho: YAG, Er:YAG, Er, Cr:YSGG Nd: YAP, GaAs (diode), and argon (Table 3).The following description pertains to those laser wavelengths and waveforms currently available to dentistry. Shorter wavelengths and pulse widths combined with higher-power densities as seen with some medical and industrial lasers bring with them other interaction phenomena that are not currently relevant to dental applications and, therefore, will not be discussed in this article.

The energy emitted by a laser is essentially a light of one color (i.e., monochromatic) and, therefore, of one wavelength. The photons comprising the energy beam are emitted as a coherent (in phase), unidirectional, monochromatic light that can be collimated in to an intensely focused beam that exhibits little divergence. The focused energy beam will interact with a target material by being absorbed, reflected, or scattered. In the case of biologic tissues, the laser energy is absorbed by the target surface tissues and will only exhibit scattering in cases of deep tissue penetration. The absorbed light energy is converted to heat and constitutes a photo thermal event. Depending on various parameters, the absorbed energy can result in simple warming, coagulation, or excision and incision through tissue vaporization. Variable parameters affecting energy absorption include emission wavelength, power (watts), waveform (continuous orpulsed), pulse duration, energy/pulse, energy density, duration of exposure, peak power of pulse, angulation of the energy delivery tip to the target surface, and optical properties of the tissue.

Although the wavelength of light is the primary variable that determines the extent of energy absorption by a target tissue, one must also be aware of the optical properties of the tissue. The optical properties of a tissue dictate, to a great extent, the interaction with specific laser wavelengths.

Table 1 Characteristics of Laser Wavelengths Used in Clinical Dentistry

Laser Type	Common Abbreviation	Wavelength	Waveform	Delivery Tip	Reported Periodontal Applications
Carbon dioxide	CO2	10.6 mm	Gated or continuous	Hollow waveguide; beam focused when 1 to 2 mm from target surface	Soft tissue incision and ablation; subgingival curettage
Neodymium:yttriumaluminum-Garnet	Nd:YAG	1.064 mm	Pulsed	Flexible fiber optic system of varying diameters; surface contact required for most procedures	Soft tissue incision and ablation; subgingival curettage and bacterial elimination
Holmium:yttriumaluminum-Garnet	Ho:YAG	2.1 mm	Pulsed	Flexible fiber optic system; surface contact required for most procedures	Soft tissue incision and ablation; subgingival curettage and bacterial elimination
Erbium:yttriumaluminum-Garnet	Er:YAG	2.94 mm	Free-running pulsed	Flexible fiber optic system or hollow waveguide; surface contact required for most procedures	Soft tissue incision and ablation; subgingival curettage; scaling of root surfaces; osteoplasty and ostectomy
Erbium, chromium:yttriumselenium-galliumgarnet	Er,Cr:YSGG	2.78 mm	Free-running pulsed	Sapphire crystal inserts of varying diameters; surface contact required for most procedures	Soft tissue incision and ablation; subgingival curettage; osteoplasty and ostectomy
Neodymium:yttriumaluminum-Perovskite	Nd:YAP	1,340 nm	Pulsed	Flexible fiber optic system; surface contact required for most procedures	Soft tissue incision and ablation; subgingival curettage and bacterial elimination
Indium-galliumarsenide-phosphide; Gallium aluminumarsenide;galliumarsenide	InGaAsP (diode) GaAlAs (diode) GaAs (diode)	Diodes can range from 635 to 950 nm	Gated or continuous	Flexible fiber optic system; surface contact required for most procedures	Soft tissue incision and ablation; subgingival curettage and bacterial elimination
Argon	Ar	488 to 514 nm	Gated or continuous	Flexible fiber optic system	Soft tissue incision and ablation

For example, optical properties of tissues comprising the periodontium include such factors as pigmentation, water content, mineral content, heat capacity that accounts for both thermal conductivity and tissue density, and latent heats of transformation (i.e., denaturing of proteins, vaporization of water, and melting of mineral). Boneis considered the classic composite tissue, being comprised of 67% inorganic minerals (calcium hydroxyapatite) and 33% collagen and non-collage nous proteins. By contrast, gingiva is comprised of varying densities of fibrous connective tissue, associated extracellular matrix components, and a high content of water (70%). Additionally, the gingivae frequently exhibit melanin pigmentation. Other factors that likely play a role in laser-tissue interactions include the physiologic and mechanical processes of heat conduction and dissipation, the degree of tissue inflammation and vascularity, and the availability of progenitor cells to participate in the healing process.

Each wavelength of laser energy is absorbed to agreater or lesser degree in water, pigment, or hydroxyapatite. As examples, the CO2 laser (10,600-nmwavelength) has a high absorption coefficient in water and consequently is well suited for soft tissue surgery but currently has no scientifically well-supported clinical application to mineralized tissues. The Nd: YAG(1,064-nm wavelength) and diode lasers (800- to950-nm wavelength) have lower absorption coefficients in water than CO2 lasers but are preferentially absorbed in pigmented tissues, and the Er, Cr: YSGG and Er: YAG wavelengths (2,780 and 2,940 nm, respectively)are highly absorbed in both water and hydroxyapatite. Given the diversity of available wavelengths, the prudent clinician should first determine the specific clinical treatment goals and then select the technology (laser or otherwise) best suited to achieve the desired endpoint(s).

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.

Table 2 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

Table 3 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 laser

Soft lasers are of cold (athermic) energy emitted as wavelengths; those are thought to stimulate cellularactivity. These soft lasers generally utilize diodes and the manufacturers claim that these lasers can aid healing of the tissue, reduces inflammation, edema, and pain. Clinicalapplication includes healing of localized osteitis, healing ofaphthous 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)

Hard lasers can cut both soft and hard tissues. Newervariety can transmit their energy via a flexible fiber opticcable. Presently more common type clinically used, underthis 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 2.1micro-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-outputdiodes
- 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, CO2o Excimer-eg. ArF, KrClo 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.[3] 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 excitedatom is stimulated to emit a photon before the processoccurs 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.[10]

Laser is a type of electromagnetic wave generator.[11] 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 thesame frequency and energy.

2. **Coherent**: all waves are in a certain phase and arerelated to each other, both in speed and time.
3. **Collimated**: all the emitted waves are nearlyparallel and the beam divergence is very low.[12]

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.[13] 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 issue, optical properties of the tissue, such as pigmentation, water content, and mineral content, can also influence the extent of energy absorbed.[14]

The term 'waveform' describes the manner in which laserpower is delivered over time, either as a continuous or as apulsed 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 ininterrupted bursts, thereby countering the build-up of heat in the surrounding tissues.[15] 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 hemostas is, bactericidal effect, and minimal wound contraction[16-18]. 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.[19] 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.

Precautions and Risks Associated with Clinical use of Lasers:[19]

Precautions before and during Irradiation

1. Use glasses for eye protection (patient, operator,and assistants).
2. Prevent inadvertent irradiation (action in noncontactmode).
3. Protect the patient's eyes, throat, and oral tissuesoutside the target site.
4. Use wet gauze packs to avoid reflection fromshiny metal surfaces.

Table 4 Laser types and its applications

Types	Active medium	Dental application
Excimer Lasers	Argon –fluoride(ArF) Xenon-chloride (XeCl)	Hard tissue ablation, dental calculus Removal
Gas lasers	Argon (Ar)	• Curing of composite materials, tooth whitening, intraoral soft tissue surgery, sulcular debridement (subgingival curettage in periodontitis and periimplantitis)
	Helium-neon (HeNe)	• Analgesia, treatment of dentin hypersensitivity, apthous ulcer treatment
	Carbon dioxide(CO_2)	• Intraoral soft tissue and soft tissue surgery, aphthous ulcer treatment, removal of gingival melanin pigmentation, treatment of dentin hypersensitivity, analgesia
Diode Lasers	Gallium-arsenide-phosphorous(InGaAsP) Galium-aluminium-arsenide (GaAIAs) 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	Selective ablation of dental plaque and Calculus
	Neodymium:yttrium-aluminium-garnet(Nd:YAG)	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), scaling of 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

5. Ensure adequate high speed evacuation to capture the laser plume.

Potential risks

1. Excessive tissue destruction by direct ablation and thermal side effect
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 diodelasers 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 porphyromonasgingivalis and actinobacillusactinomycetemcomitans.[20]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.[21] Gingivaldepigmentation 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 recont our 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.[22]

The use of these lasers is limited to ginivectomy, g ingivoplasty, 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.[23]

CONCLUSION

Currently, among the different types of lasers available, Er:YAG and Er, Cr:YSGG laser possess characteristics suitable for dental treatment.

In addition, its bactericidal effect with elimination oflipopolysaccharide, 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.

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How to cite this article:

Muzafar Ahmad Bhat *et al*.2016, Application of Lasers In Periodontics: A Review of The Literature. *Int J Recent Sci Res.* 7(6), pp. 11924-11929.