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REVIEW ARTICLE

USE OF LASERS IN PERIODONTICS

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ABSTRACT

In the past 100 years, there has been extensive development of the mechanical cutting devices used in dentistry. One of the most exciting developments in medical technology is the laser. The past decade has been a veritable explosion of research into the clinical applications of lasers in dental practice. Based on Albert Einstein's theory of spontaneous and stimulated emission of radiation, Maiman developed the first laser prototype in 1960. The first application of laser to dental tissue was reported by Goldman in 1972 and Stern and Sognnaes published an article describing the effects of ruby laser on enamel and dentin. Compared with the use of a conventional scalpel, lasers can cut, ablate and reshape the oral soft tissues more easily, with minimal or no bleeding and little pain as well as no or only a few sutures. Laser surgery occasionally requires no local anesthetic or only a topical anesthetic. Minimal wound contraction and scarring are other advantages of laser surgery. Less postoperative pain in patients is also frequently observed by clinicians, but this has not yet been scientifically proven.

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INTRODUCTION

Properties of light and its applications have always fascinated the humankind and thus its use in medicine can be traced to ancient times. (An Overview of Lasers in Dentistry, 2008) Developments in physics at the beginning of the twentieth century laid the foundation for laser theory postulated by Albert Einstein (An Overview of Lasers in Dentistry, 2008; Research, Science and Therapy committee of the AAP, 2002), which culminated in the invention of this special form of light in 1960. Since then, LASERS "Light Amplification by Stimulated Emission of Radiation" have been widely used in the field of medicine and surgery. (An Overview of Lasers in Dentistry, 2008) History of lasers: Based on quantum theory, two fundamental radiation processes associated with light and matter were known before Einstein's (An Overview of Lasers in Dentistry, 2008) i.e. 1) Stimulated absorption, a process in which an atom can be excited to a higher energy state through means such as heating, light interaction, or particle interaction; and 2) Spontaneous emission, the process of an excited atom decaying to a lower energy state spontaneously, by itself. Einstein's breakthrough was the addition of a third alternative, Stimulated emission, the reverse of the stimulated absorption process. Stimulated emission occurs when there are more excited atoms than atoms that are not excited. The impact of this situation was exemplified by the work of Charles H Townes in 1951, where he proposed the concept of 'MASER- Microwave Amplification by Stimulated Emission of Radiation'. In 1957, another American physicist Gordon H Gould recorded his work where optical plumbing could excite light emission and hence the term Laser was first used.

In 1960, T H Maiman identified five potential uses for the laser: (Maiman *et al*., 1960; Lee *et al*., 2007)

1. The first true amplification of light
2. A tool to probe matter for basic research
3. High- power beams for space communications
4. Increasing the number of available communication channels
5. Concentrating light for industry, chemistry and medicine.

A few years later, Maiman foresaw the use of lasers as a bloodless surgical tool in the treatment of malignancies and as a dentist's drill. The first ruby laser effect on dentin and enamel was reported in 1964 by Stern and Sognnaes (Stern *et al*., 1964) and later by Goldman *et al*. (Goldman *et al*., 1964), Myers and Myers (Myers *et al*., 1985) suggested the use of lasers for oral soft tissue surgery with the Nd:YAG (Neodymium: Yttrium Aluminium Garnet) laser, the prototype published by Snitzer in 1961 (Snitzer *et al*., 1961; Mahajan, 2011). However, it was found out that Nd:YAG lasers are not suitable for the treatment of dental hard tissues because of its difficulty in cutting hard tissues as well as its deeply penetrating effects causing potential pulpal damage (Wigdor *et*

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al., 1993). Since then, enormous amount of work has been carried out using different lasers like CO_2 (Carbon Dioxide), Argon lasers, Erbium, Holomium and Excimer YAG lasers and diodes (Mahajan, 2011). Lasers are typically named according to their active element(s) that are induced to undergo the stimulated quantum transitions, that in turn creates the energy beam (Midgley *et al*., 1990). The characteristics of a laser depend on its wavelength (Research, Science and Therapy committee of the AAP, 2002) (the horizontal distance between any two corresponding points on a wave) (An Overview of Lasers in Dentistry, 2008) as it effects both the clinical applications and design (Seyyedi *et al*., 2012). Usually, 193nm to 10,600nm wavelengths of lasers are used in the field of medicine and dentistry. The most common lasers used in dentistry today are the CO_2, Nd:YAG which have a wavelength of 10,600nm (far infrared) and 1064nm (near infrared), respectively. These lasers use a quartz fiber incorporating a 630nm coaxial helium- neon laser in the device, which acts as an aiming beam to facilitate for use as they are infrared range and are not visible. Soft tissue thermolysis and bacterial decontamination can be done by lasers like Argon (488nm, 514nm) (Finkbeiner *et al*., 1995), Diode (800- 830nm, 980nm) (Moritz *et al*., 1998) and Nd:YAG (1064nm) (Neil *et al*., 1997; Liu *et al*., 1999; Raffetto *et al*., 2001), but these are unsuitable for calculus removal as they have low surface thermal absorption. Erbium family of lasers like Er:YAG and ErCrYSGG have shown promising results as their capability to ablate both hard and soft tissues.

Working of a laser:

The laser light is distinguished from ordinary light by 2 properties:

1) It is monochromatic- generates a beam of single colour;
2) It is coherent- identical in physical size and shape and
3) Collimated- parallel rays of light (Clayman *et al*., 1997). Amplification is a part of this process that occurs inside the laser. The centre of the laser (called the laser cavity) is made up of active medium, pumping mechanism and optical resonator.

The active medium is composed of chemical elements, molecules or compounds. Surrounding this active medium is an excitation source. This pumping mechanism pumps energy into the active medium and the energy gets absorbed by the electrons in the outermost shell of the active mediums atoms. A population inversion occurs when more electrons from the active medium are in the high energy level shell farther from the nucleus. The electrons in this excited state give energy in the form of photon and this is called as spontaneous emission (Mahajan, 2011). Completing the laser cavity are two mirrors that are placed parallel which act as optical resonator, reflecting waves back and forth. A cooling system, focusing lenses and other controlling mechanisms complete the mechanical components. Stimulated emission is the process by which laser beams are produced inside the laser cavity. The light waves produced by the laser are a specific form of radiation or electromagnetic energy (An Overview of Lasers in Dentistry, 2008; Mahajan, 2011). Laser delivery system: Shorter wavelength instruments have small, flexible fiberoptic systems with bare glass fibers that deliver the laser energy to the target tissue. These include potassium titanyl phosphate (KTP), Diode and Nd:YAG. The Erbium and CO_2 laser wavelengths are absorbed by water, (major component of conventional glass fibers) are constructed with special fibers capable of transmitting wavelength with semi flexible hollow waveguides or articulated arms. Some systems employ small quartz or sapphire tips that attach to the laser device for contact with the target tissue while others employ non-contact tips. The diameter of the fiber, hand piece and tip play a significant role in the delivery of energy.

Emission modes: laser device can emit energy in two modalities: 1) constant on or 2) pulsed on and off. The pulsed can be divided into gated and free- running modes in delivering energy to the target tissue.

1. Continuous- wave mode- beam is emitted at only one power level as long as the operator depresses the foot switch.
2. Gated- pulsed mode- there are periodic alterations of the laser energy, similar to a blinking light.
3. Free- running pulsed mode- or true- pulsed mode. Large peak energies of laser light are emitted for microseconds followed by a relatively long time in which laser is off.

Laser effects on tissue: there may be four different interactions with the target tissue: 1) Reflection 2) Transmission 3) Scattering and 4) Absorption

Reflection is the beam being redirected off the surface, with no effect on the target tissue (Frehtzen *et al*., 1990). The second interaction is Transmission of the laser energy directly through the tissue, with no effect on the target tissue (Cobb *et al*., 2006). The third tissue interaction is scattering of the laser light which weakens the intended energy. Absorption of the laser energy by the intended target tissue is the usual desirable effect (Dederich, 2004).

Lasers are classified as (Dang *et al*, 2013):

1) According to light spectrum

UV Light	100nm- 400nm	Not used in dentistry
Visible Light	400nm- 750nm	Most commonly used in dentistry (Argon)
Infrared Light	750nm- 1000nm	Most dental lasers are in this spectrum

2) According to the material used

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

3) Soft lasers and Hard lasers

There are various lasers available that can be used for periodontal treatment. They can be divided into soft tissue lasers or soft and hard tissue lasers. Nd:YAG, Carbond Dioxide and semiconductor diode lasers can be categorized as the soft tissue group whereas the Erbium family of lasers are capable of performing both hard and soft tissue function and hence are more beneficial for periodontal treatment (Moritz *et al*., 1998). Types of lasers (Application of Lasers in Periodontics, 2009):

On the basis of output energy

- Low output, soft or therapeutic. Ex- low- output diodes

Laser type, Active medium and color	Wave length (in nm)	Waveform	Delivery system	Applications in periodontal treatment
Gas- Carbon Dioxide (CO_2) (Infrared)	10600	Gated or Continuous	Hollow waveguide/ articulated arm	Soft tissue incision and ablation, analgesia, treatment of apthous ulcer, removal of melanin pigmentation, dentinal hypersensitivity, decontamination of implant, subgingival curettage
Gas- Helium- neon (He-Ne) (Red)	632.8	Gated or continuous	Articulated arm	
Gas- Argon (Ar) (Blue)	635- 950	Gated or continuous	Flexible fiberoptic system	Soft tissue incision and ablation, caries and calculus removal, subgingival curettage
Diode- Indium- gallium- arsenide- phosphorus (InGaAsP) (Red)	655	Gated or continuous	Flexible fiberoprtic system	Caries and calculus detection, soft tissue incision and ablation, bacterial elimination, pulpotomy, root canal disinfection, sulcular debridement, caries removal, treatment of apthous ulcer, melanin pigment removal.
Gallium- aluminium-arsenide (GaAlAs) (Red- Infrared)	670- 830	Gated or continuous	Flexible fiberoprtic system	
Gallium- arsenide (GaAs) (Infrared)	980	Gated or continuous	Flexible fiberoprticsystem	
Indium- gallium- arsenide (InGaAs) (Infrared)	980	Gated or continuous	Flexiblefiberoprtic system	
Solid state- Neodymium doped- yttrium- aluminium- garnet (Nd:YAG)(Infrared)	1064	Pulsed	Flexible fiberoptic system	Soft tissue incision and ablation, sulcular debridement, analgesia, treatemtn of dentin hypersensitivity, root canal disinfection, pulpotomy, removal of melanin pigment
Erbium group- Erbium: yttrium- aluminium- garnet (Er:YAG) (Infrared)	2940 2780	Free running pulsed mode	Flexible fiberoptic Air cooled fiberoptic	Soft tissue incision and ablation, subgingival curettage, scaling, root conditioning, osteoplasty and ostectomy, degranulation and decontamination of implants, treatment of dentine hypersensitivity
Erbium, Chromium: yttrium- selenium- gallium- garnet (Er,Cr:YSGG)(Infrared)	488- 514	Gated or continuous	Flexible fiberoptic system	Soft tissue incision and ablation, composite curing, tooth whitening, sulcular debridement for periodontium and peri- implant tissues

- High output, hard or surgical. Ex- CO_2, Nd:YAG, Er:YAG

On the basis of state of gain medium

- Solid state. Ex- Nd:YAG, Er:YAG, ErCr:YAG
- Gas. Ex- HeNe, Argon, CO_2
- Excimer.Ex- ArF, KrCl
- Diode. Ex- GaAlAs

On the basis of oscillation mode

- Continuous wave. Ex- CO_2, Diodes
- Pulsed wave. Ex- Nd:YAG, Er:YAG

In the table given above, is a summary of the current types of lasers, active medium, color wavelength, waveform, delivery system and their clinical applications (Mahajan, 2011; Dang *et al*., 2013)

Other applications of laser include

Detection of dental caries and subgingival calculus by laser fluorescence. Use of laser Doppler flowmetry to assess dental pulp blood flow Lower power lasers are used for photochemical activation of oxygen releasing dyes (PAD) (Aoki *et al*, 2004; Cohen *et al*, 2002). Oxygen released from the dyes causes membrane and DNA change in microorganisms. Photodynamic therapy is a more powerful photochemical reaction initiated by laser and is used to generate reactive oxygen species. This has been employed in the treatment of malignancies of oral mucosa (Chen *et al*., 2002; Schwarz *et al*., 2009).

Advantages and disadvantages of laser treatment: (Chen *et al*., 2002; Schwarz *et al*., 2009; Walsh, 2003)

Advantages:

- Greater haemostasis
- Bactericidal effect
- Minimal wound contraction
- Cut, ablate and reshape oral tissues easily without or with minimal bleeding
- Analgesia
- No or only few sutures required

Disadvantages:

- Laser irradiation can interact with tissues even in non-contact mode
- Destruction of attachment apparatus and gingival tissue in periodontal pockets
- Thermal injury to root surface, gingival tissues and pulp.

Precautions to be taken while using lasers: Lasers should be operated in an area where there is limited access and minimal reflective surfaces. Specific protective eyewear should be worn at all times by the operator and patient. Another important treatment protocol is a properly trained staff regarding laser safety. Usage of wet gauze pads to avoid reflection from shiny metallic surfaces.

Conclusion

From time to time, the options available to clinicians are increasing and laser is one such field that yields a promising result. It serves as an alternative or adjunctive to conventional treatment procedures in periodontics. The Erbium family of lasers possess characteristics suitable for both hard and soft tissues with minimal damage. Additionally other effects like removal of bacterial plaque and calculus, irradiation effect limited to an ultra-thin layer of tissue, bactericidal effect with elimination of lipopolysaccharide, bone and soft tissue repair and scaling and root planning make it a suitable use in this field. In order to have a successful treatment outcome, motivation to practice oral hygiene before, during and after periodontal treatment will help in achieving a stable periodontium.

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