Review

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An insight into Lasers in Periodontics:A Review

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Abstract

Lasers have been used in dentistry for more than two decades. The use of lasers for periodontal treatment has become more complicated because the periodontium consists of both hard and soft tissues. Various literature offers knowledge regarding the use of specific lasers approved for soft or hard tissue applications. The purpose of this review article is to analyse the applications of laser for soft and hard tissue management in field of periodontics.

Key Words: Lasers; periodontitis

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INTRODUCTION

In the past 100 years there has been extensive development of the mechanical cutting devices used in dentistry. However, while considerable progress has been made in this area of mechanical cutting, dental patients are still afraid of the noise and vibration produced by the mechanical action of the air turbine or ultrasonic scalers. From the end of the 20th century until now, there has been a continuous upsurge in the development of laser-based dental devices based on photo-mechanical interactions. It has been nearly 50 years since the first laser device was produced. Lasers have been successfully used since the mid-1960s for precise photocoagulation of retina. Thus ophthalmologists were the pioneers of laser application. Since then, lasers have been used in many industrial and scientific applications. Based on Albert Einstein's theory of spontaneous and stimulated emission of radiation. Maiman[1] (1960) developed first laser prototype. Thus the ruby laser was created. Shortly after Snitzer[2] (1961) published prototype for the Nd: YAG lasers. The first report of laser application for the treatment of dental caries was published in Nature in 1964 by Goldman et al[3]. However, it was found that those lasers designed for soft tissue removal were not suitable for the treatment of dental hard tissues. The Nd: YAG laser was not appropriate for dental caries treatment because of its difficulty in cutting hard tissues as well as its deeply penetrating effects causing potential pulpal damage[4]. Thus, 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. The lasers that show the most promise for hard tissue surgery are the erbium: YAG (Er: YAG) (2940 nm wavelength) and erbium, chromium: yttrium, scandium, gallium, garnet (Er, Cr: YSGG) (2790 nm) lasers. The absorbance of the Er: YAG laser in water is about 2.5-, 10- and 15,000-times higher than that of Er, Cr: YSGG, CO2 and Nd: YAGlasers, respectively [5, 6]. Because of the potential for possible soft and hard tissue applications, use of this laser has been investigated for scaling, root debridement and periodontal and peri-implant surgeries in periodontal therapy [7].

Laser Physics

Light is a form of electromagnetic energy that behaves as a particle and a wave. The basic unit of this energy is called a photon. Laser light is one specific colour, a property called monochromacity. Clinical lasers are plotted according to their wavelengths. Laser light is monochromatic, focussed collimated and coherent. 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 subsequent photon and so on. Dental lasers are visible invisible, infrared, or non-ionising portion of electromagnetic spectrum.

Components

A laser consists of a laser medium in a resonant cavity with a power supply and a cooling system with a control. Lasers are named after active medium-gas e.g. Co2 laser, a solid crystal Rod e.g. Er: YAG laser or as solid state electronic device in diode.

Laser Tissue Interaction

When laser light reaches a tissue, it can reflect, scatter, be absorbed or be transmitted to the surrounding tissues.In biological tissue, absorption is mainly due to the presence of free water molecules, proteins, pigments, and other macromolecules. The absorption coefficient strongly depends on the wavelength of the incoming laser irradiation. All dental lasers exert their desired clinical effect on patient target tissue by a process called

Absorption

This target may consist of hemoglobin, melanin, hard tissues including natural tooth structure, carious enamel and dentin, dental calculus and even bone.

Laser Wavelength

Importance of wavelength

Lasers used in dentistry today consists of various wavelengths delivered as either a continuous, pulsed (gated) or running pulse form. Depending on various parameters, the absorbed energy results in simple warming, coagulation or excision and incision through tissue vaporization. Variable parameters affecting energy absorption include emission wavelength, power (watts), wave form i.e., continuous or pulsed) pulse duration, energy/pulse. Each wavelength of laser energy is absorbed to a greater or lesser degree in water or hydroxyapatite given the diversity of available wavelength.

Types of lasers

Diode- Diode is a solid active medium laser, manufactured from semiconductor crystals using some combination of aluminium or indium, gallium, and arsenic. This ‘‘chip’’ of material has the optical resonator mirrors directly attached to its ends, and an electrical current is used as the pumping mechanism. It consists of Solid active medium-semiconductor crystals. Diode has a continuous or gated pulse mode in contact mode with a wavelength-810,940 & 980nm. It is poorly absorbed in water, high absorption in melanin and hemoglobin and serves as an excellent soft tissue laser.Erbium Laser- It was introduced by Zharikov in 1974[9]. Distinct wavelengths – Er.Cr.YSGG-2780nm & Er.YAG-2940nm. Delivered fiber optically or hollow wave guide in free running pulse mode. Caries removal and tooth preparation. Bone removal and can remove hard and soft tissues without charringCO_2 Laser – (Patel et. al.1964)[10].Active medium laser wavelength is 10,600 nmcut and coagulate soft tissue, and it has a shallow depth of penetration into tissue, it can treat mucosal lesions.Highest absorption in hydroxyapatite of any dental laser, about 1000 times greater than erbium.

Nd:YAG Laser-(Maeyers&Maeyers 1985)[11].Solid active medium- garnet crystal combined with rare earth elements yttrium and aluminum, doped with neodymium ionsemission wavelength of 1064 nmfree-running pulsed modeabsorbed by melanin but is less absorbed by hemoglobin and is approximately 90% transmitted through waterusing the high peak powers of a free running pulse emission with relatively long tissue cooling time, common clinical applications are for cutting and coagulating of dental soft tissues and sulcular debridement[12,13].

Holmium: YAG

The manufacture of the only holmium laser dental instrument ceased several years ago. It contains a solid crystal of yttrium aluminium garnet sensitized with chromium and doped with holmium and thulium ions and is fibre-optically delivered in free-running pulsed mode. The wavelength produced by this laser is 2100 nm, also in the near infrared portion of the invisible nonionizing radiation spectrum. It is absorbed by water 100 times greater than Nd: YAG is, and using high peak powers it can ablate hard, calcified tissue; however, as a soft-tissue instrument it does not react with hemoglobin or other tissue pigments[14]. The holmium laser is frequentlyused in oral surgery for arthroscopic surgery on the temporomandibularjoint and has many medical applications[15].

Laser Delivery system

There are three different ways in which laser beam can be delivered- first is the articulated arms, second is the hollow wave guide and the third is the glass fibre optic cable.

Laser emission modes

Three emission modes: Continuous wave-beam is emitted at only one power level for as long as the operator depresses the foot switch. Gated pulsed mode-achieved by the opening and closing of a mechanical shutter in front of the beam path of a continuous wave emission. Free running pulse mode-large peak energies of laser light are emitted for a short time span, usually in microseconds, followed by a relatively long time in which the laser is off

Clinical implications of lasers on soft tissues and hard tissues in oral cavity

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, thus being a viable alternative. Laser surgery occasionally requires no local anaesthetic, or only a topical anesthetic.[34] It is viable alternative to various soft tissue procedures such as frenectomy, gingivectomy and gingivoplasty, de-epithelization of reflected periodontal flaps, removal of granulation tissue, second stage exposure of dental implants, lesion ablation, incisional and excisional biopsies of both benign and malignant lesions, irradiation of aphthous ulcers, coagulation of free gingival graft donor site, gingival depigmentation (Cobb 2006)[16].

Advantages of lasers (Bader 2000, Powell 1992)[17]

Dry and bloodless surgery.Instant sterilization of the site.Reduced bacteremia. Reduced mechanical trauma. Minimal post-operative swelling and scarring.Minimal post-operative pain.Lasers can penetrate those sites which conventional instrumentation cannot access. Lasers can achieve excellent tissue ablation with bactericidal and detoxification effects. Coagulation and hemostasis can be achieved at 60 degree Celsius. Less wound contraction. Pain reduction may be due to protein coagulum that is formed on the wound surface, thereby acting as a biological dressing and sealing the ends of sensory nerves (Schuller1990)[18].The rapid wound healing after using lasers may be related to the photo modulation. The photo modulation (FBM) or low level laser therapy is application of electromagnetic energy in the red or infrared region to damaged or diseased tissue. LLLT contributed to larger expression of collagen and elastic fibers during the early phases of wound healing process (Pugliese et al.2003)[19] also works at cellular level by promoting faster healing, with reduction in toxins via accelerating lymphatic flow and increasing blood supply, thereby helps to reduce pain, enhance repair and induce regeneration.Oral Hard Tissues-lasers are used for the purposes of ostectomy, osteoplasty, and implant site preparation. Given that laser/biologic tissue interaction are photothermal events that, in turn are wavelength dependent, with the possible exemption of two wavelengths (Er:YAG and Er,Cr:YSGG)the effect of most dental lasers on bone is generally detrimental(Cobb,2006)[16].When considering laser mediated osteotomy or ostectomy, the Er, Cr: YSGG appears to be popular laser. Kimura et al (2001)[20]evaluated the morphological and temperature changes in canine mandibular bone following irradiation with Er: Cr: YSGG laser and found no changes in calcium/phosphate ratio (EDX-analysis) and no evidence of charring and melting. (Abu serriah et al.2004; Stubinger et al., 2007a, b) [21].Treatment in surgical pocket therapy: Laser mediated periodontal therapy is predicted on concept of sub gingival curettage regarding reattachment and regeneration of the attachment apparatus. Various studies suggests use of lasers in periodontal disease management using CO_2,Nd:YAG,Diodes,Er:YAG.Results of these studies are conflicting as some studies suggests its use as monotherapy (Romanos, 1994;Gold and Vilarch,1994)[22]while others are contradictory (Yukna et.al.2007;Radvar et.al.,1996;Haris et al.2004)[23.] Various lasers have been applied in the field of implant dentistry for uncovering the submerged implant (second-stage) prior to placement of the healing abutment. Use of lasers in these procedures may have several advantages, including improved haemostasis, production of a fine cutting surface with less patient discomfort during the postoperative period, and favourable and rapid healing following abutment placement, thus permitting a faster rehabilitative phase [24.] There also is minimal tissue shrinkage after laser surgery, which assures that the tissue margins will remain at the same level after healing as they are immediately after the surgery. In addition, the use of the laser can eliminate the trauma to the tissue of flap reflection and suture placement (assuming adequate zones of keratinized tissue and the knowledge of where the implant has been placed)

Bactericidal and detoxification effects

The limitations of conventional therapy have led to a shift in emphasis from a purely mechanical approach to the use of novel technical modalities having additional bactericidal effects, such as lasers. The defocus mode of the CO2 laser has root conditioning effects, such as smear layer removal, decontamination[25, 26, 27] and the preparation of a surface favourable to fibroblast attachment. Regarding the Nd: YAG laser, several researchers reported a decontamination effect [28] and the inactivation of the endotoxins in the periodontally diseased root surface [29]. The Er: YAG laser exhibits a high bactericidal effect against periodontopathic bacteria at a low energy level [30, 31], and this laser also has the potential to remove toxins diffused into the root cementum, such as bacterial lipopolysaccharides[32]. The bacterial killing effect of argon laser radiation may be effective in the treatment of clinical infections caused by biofilm-associated species, such as Prevotella and Porphyromonas [33, 34]

LIMITATIONS

First, the high financial cost of a laser apparatus is a significant barrier for laser utilization by periodontal practitioners. Second, each laser has different characteristics because of their different wavelengths. Thus, laser users should know the fundamental characteristics of each laser. However, only a few academic institutions provide proper and systematic education of the use of lasers in dentistry. For this reason, it is difficult for the users to learn all aspects of the techniques and precautions required for the newer technologies. Improper irradiation of teeth and periodontal pockets by lasers can damage the tooth and root surfaces as well as the attachment apparatus at the bottom of the pocket.

Risks

1. Possible damage to the underlying bone and dental pulp should also be considered.

1. Caution before and during irradiation.
2. Use of glasses for eye protection (patient, operator and assistants)
3. Precautions for inadvertent irradiation and reflection from shiny metal surfaces
4. Protection of patients throat & oral tissues outside the target site
5. Accurate foot pedal control
6. Adequate high speed evacuation to capture the laser beam

2. Risk of thermal injury during interaction with the tissues

1. Understanding of the penetration depth of each laser
2. Thermal injury to the root surface, gingival tissue, pulp and bone tissue
3. Effective use of water spray to minimize heat generation

3. Risk of excessive tissue destruction by direct ablation and thermal side effects

1. Excessive ablation of root surfaces and gingival tissue during pocket irradiation
2. Destruction of the attachment apparatus at the bottom of pockets during pocket irradiation.
3. Bone and root surface alterations during gingival soft tissue surgery or pocket irradiation
4. Damage of the tooth enamel by inadvertent irradiation

CONCLUSION

The application of lasers has been recognized as an adjunctive or alternative approach in periodontal and peri-implant therapy. Soft tissue surgery is one of the major indications of lasers. CO2, Nd: YAG, diode, Er: YAG and Er, Cr: YAG lasers are generally accepted as useful tools for these procedures. Laser treatments have been shown to be superior to conventional mechanical approaches with regards to easy ablation, decontamination and haemostasis, as well as less surgical and postoperative pain in soft tissue management. Laser or laser-assisted pocket therapy is expected to become a new technical modality in periodontics. The Er: YAG laser shows the most promise for root surface debridement, such as calculus removal and decontamination. Concerning the use of lasers for bone surgery, CO2 and Nd: YAG lasers are considered unsuitable because of carbonization and degeneration of hard tissue. Currently, the Er: YAG laser is safe and efficient for periodontal bone surgery when used concomitantly with water irrigation. Application of lasers has also been considered in implant therapy. Based on previous reports, lasers, especially the Er: YAG laser, hold promise as an alternative treatment in the treatment of peri-implantitis. Application of photodynamic therapy in the treatment of periodontitis and peri-implantitis is a novel approach. However, to date the real superiority of photodynamic therapy for clinical improvements has not been demonstrated. Further studies are encouraged to understand in more detail the effects of lasers on biological tissues, including the periodontium, in order to ensure their safe and effective application during periodontal treatment. Among lasers currently available, the Er: YAG laser seems to provide the most suitable characteristics for various types of periodontal treatment. The scientific basis and tissue effects of dental lasers have been discussed. It is most important for the dental practitioner to become familiar with those principles and then choose the proper laser(s) for the intended clinical application. Each wavelength and each device has specific advantages and disadvantages. The clinician who understands these principles can take full advantage of the features of lasers and can provide safe and effective treatment.

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