Review Article

Laser: Supremacy ray in Periodontics

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INTRODUCTION

The pathogenesis of periodontal disease and the methods of treating it have undergone radical changes in the past 30 years [1]. The current model for periodontal disease includes microbial components, host inflammatory responses, and host risk factors that contribute to the advancement of this disease [2,3]. The pathogenic bacterial plaque in the susceptible host triggers an immune response that results in inflammation and changes in the metabolism of the connective tissue and bone [4-6]. This disease can have periods of intense activity and periods of dormancy. Initial periodontal therapy now includes nonsurgical debridement of the tooth structure, local delivery of antimicrobials, host modulators, and laser reduction of sulcular bacteria with laser coagulation of the treatment site [7].

For many years now research in laser therapies in the field of periodontics is progressing steadily. In the beginning lasers were recommended only for soft tissue surgeries, however in the past few decades its use has been explored in various other periodontal procedures and integrates them into spectrum of laser supported therapies. Although there is still ambiguity in scientific literature about application of lasers we cannot ignore the growing popularity of lasers in our field claiming its unique advantage over conventional approaches [8].

LASER PHYSICS

Laser energy is made up of small particles known as photons, which move in waves. All lasers are monochromatic, collimated and coherent. They are one colour, and the light is invisible to naked eye because the laser operates outside of the visible range of the eye. Lasers are highly focused, unidirectional, and efficient; all of which makes them such a dependable tool in dentistry. Wavelength is the distance between any two corresponding points on the wave. Each wavelength has velocity, which is the speed of light (1,86,000 m/sec), and amplitude, which is the vertical movement of the total height of the wave from peak to peak. The characteristics of a laser depend on its wavelength and it effects the clinical applications and design of the laser [9]. The wavelength of the laser used in medicine and dentistry ranges from 193nm to 10,600nm, representing a broad spectrum from ultraviolet to far infrared range.

The lasers most commonly used in dentistry the CO_2 and ND:YAG have wavelength of 10,600nm (far infrared) and 1064 (near infrared) respectively. Frequency is another important factor in working with lasers. It is relative to the number of complete oscillations per unit time of a wave and is measured in hertz, which are units of frequency in cycles per second.

LASER COMPONENTS

An optical cavity is at the center of the device. The core of the cavity comprised of chemical elements, molecules, or compounds and is called the active medium. Lasers are generically named for the material of the active medium, which can be a container of gas, a crystal, or a solid-state semiconductor. There are two gaseous active medium lasers used in dentistry: argon and CO_2. There are two mirrors, one at each end of the optical cavity, placed parallel to each other. Surrounding this core is an excitation source, either a flash lamp strobe device or an electrical coil, which provides the energy into the active medium. There is a pumping mechanism which develops a population inversion in the active medium (electrical current discharge). An optical resonator, which amplifies and collimates the developing laser beam. A cooling system, focusing lenses, and a controller subsystem (microprocessor) complete the mechanical components.

Table 1: Type and wavelength of lasers

Laser Type	Wavelength (in nm)
Excimer laser	
Argon flouride (ArF)	193
Xenon Chloride (XeCl)	308
Gas lasers	
Argon	488 514
Helium Neon (HeNe)	637
Carbon dioxide (CO2)	10,600
Diode lasers	
Indium gallium arsenide phosphorous (InGaAsP)	655
Gallium aluminium arsenide (GaAlAs)	670-830
Gallium arsenide (GaAs)	840
Indium gallium arsenide (InGaAs)	980
Solid state lasers	
Frequency doubled alexandrite	337
Potassium titanyl phosphate (KTP)	532
Neodymiun: YAG (Nd: YAG)	1,064
Holmium: YAG (Ho:YAG)	2,100
Erbium chromium: YSGG (Er,Cr:YSGG)	2,780
Erbium: YSGG (Er:YSGG)	2,790
Erbium: YAG (Er:YAG)	2,940

LASER TISSUE INTERACTION

Laser light can have four different interactions with the target tissue, depending on the optical properties of that tissue. The first and most desired interaction is the absorption of the laser energy by the intended tissue. Tissue compounds called chromophores preferentially absorb certain wavelengths [10].

The second effect is transmission of the laser energy directly through the tissue with no effect on the target tissue. This effect is highly dependent on the wavelength of laser light. The third effect is reflection, which is the beam redirecting itself of the surface, having no effect on the target tissue. The fourth effect is a scattering of the laser light, weakening the intended energy and possibly producing no useful biologic effect [11].

LASER DELIVERY SYSTEMS [12]

- Flexible hollow wave guide or tube
- Glass fiber optic cable
- Articulated arms

ADVANTAGES

- Seals blood, lymphatic vessels and nerve fibers [13]
- Bactericidal
- Negotiates folds in the tissues.
- Minimal mechanical trauma.
- Greater comfort during and after surgery.
- Hemostasis and reduced risk of blood borne pathogens
- High patient acceptance of treatment.
- Reduced stress and fatigue for the practitioner and staff.
- Leading edge technology for a perceived higher level of patient care.

LIMITATIONS

- All lasers require specialized training and attention to safety precautions.
- Slower than traditional methods.
- No single laser can perform all desired dental applications.

CLINICAL APPLICATIONS OF LASERS IN PERIODONTICS

There are several advantages to using lasers in periodontal therapy. These advantages include hemostasis, less postoperative swelling, a reduction in bacterial population at the surgical site, less need for suturing, faster healing, and less postoperative pain [15,16]. The argon, CO_2, diode, and Nd:YAG lasers all provide what is essentially a bloodless, dry operative field [17,18].

Table 2: Uses of Lasers in Dentistry [14]

Uses of Laser
Periodontics Initial (nonsurgical) pocket therapy Nonosseous gingival surgery • Frenectomy • Gingivectomy • Graft Periodontal regeneration surgery • De-epithelialization • Removal of granulomatous tissue • Osseous recontouring
Fixed prosthetics/cosmetics Crown lengthening/soft tissue management around abutments Osseous crown lengthening Troughing Formation of ovate pontic sites Altered passive eruption management Modification of soft tissue around laminates Bleaching
Implantology Second-stage recovery Peri-implantitis
Removable prosthetics Epulis fissurata Denture stomatitis Residual ridge modification Tuberosity and Torus reduction Soft tissue modification
Pediatrics/orthodontics Exposure of teeth Soft tissue management of orthodontic patients
Oral surgery/oral medicine/oral pathology Biopsy Operculectomy Apicoectomy Oral soft tissue pathologies
Operative dentistry Deciduous teeth Permanent teeth

Lasers are generally used for gingivectomy, gingivoplasty and frenectomy and for the removal of epulis or benign tumors, with some benefits when compared with the use of a scalpel or electrosurgery [19].Gingivalhyperplasia is a typical indication for CO_2 laser treatment. The CO_2 laser is also effective in performing gingivoplasty for small tissue irregularities seen after periodontal and peri-implant surgery. The deeply penetrating lasers, such as the Nd:YAG and diode lasers, can be used to cut and reshape soft tissues [20,21]; however, these lasers have greater thermal effects, leaving a relatively thicker coagulation area on the treated surface.

The Er:YAG laser is also effective for soft tissue surgery. As this laser is the most highly absorbed in water among dental lasers [22], the width of the thermally affected layer after Er:YAG laser irradiation is minimal. Therefore, the hemostatic effect is weaker than for other lasers, but the healing of the laser wound is relatively fast and comparable to that of a scalpel wound.

Esthetic gingival procedures

Lasers can be applied in esthetic procedures such arch contouring or reshaping of gingiva and in crown lengthening. The Er:YAG laser is very safe and useful for esthetic periodontal soft tissue management because this laser is capable of precisely ablating soft tissues using various fine contact tips, and the wound healing is fast and favorable owing to the minimal thermal alteration of the treated surface [23,24].

Depigmentation is another indication for laser use in esthetic treatments. The CO_2, diode and Nd:YAG lasers can treat melanin pigmentation effectively [25]. However, in areas of thin gingiva, these lasers have a risk of producing gingival ulceration and recession as a result of their relatively strong thermal and ⁄ or deeply penetrating effects [25]. In these situations, the Er:YAG laser is more useful and safe for melanin depigmentation [24,26].

In addition, the Er:YAG laser can be utilized to remove metal tattoos [24,26]. The use of Er:YAG laser microsurgery enables effective and complete removal of the discolored gingival connective tissue, together with metal fragments, with minimum postoperative pain and little gingival recession, which cannot be achieved by conventional treatments [24,26].

Nonsurgical pocket therapy

The benefits of lasers, such as ablation, bactericidal and detoxification effects, as well as photo-bio modification, have been reported to be useful for periodontal pocket treatment, and the application of lasers has been suggested as an adjunctive or alternative tool to conventional periodontal mechanical therapy [23].

Removal of subgingival calculus

The CO_2 laser cannot be used for calculus removal because this laser readily causes melting and carbonization on the dental calculus [27]. The Nd:YAG laser is also basically ineffective for calculus removal when a clinically suitable energy is employed [28]. Unlike these lasers, the Er:YAG laser is capable of easily removing subgingival calculus without a major thermal change of the root surface in vitro [23]. Furthermore, Er:YAG laser treatment in vivo might provide selective subgingival calculus removal to a level equivalent to that provided by scaling and root planning [29].

Interestingly, the frequency-doubled Alexandrite laser (wavelength 337 nm) is able to remove supragingival and subgingival calculus as well as dental plaque in a completely selective manner without ablating the underlying enamel or cementum [30].

Bactericidal and detoxification effects

The defocus mode of the CO_2 laser has root conditioning effects, such as smear layer removal, decontamination [31] and the preparation of a surface favorable to fibroblast attachment [32]. Regarding the Nd:YAG laser, several researchers reported a decontamination effect [33] and the inactivation of the endotoxins in the periodontally diseased root surface [34]. The Er:YAG laser exhibits a high bactericidal effect against periodontopathic bacteria at a low energy level [35] and this laser also has the potential to remove toxins diffused into the root cementum, such as bacterial lipopolysaccharides [36]. 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 [37,38].

Periodontal pocket treatment

One of the possible advantages of laser treatment of periodontal pockets is the debridement of the soft tissue wall. Gold &Vilardi reported the safe application of the Nd:YAG laser (1.25 and 1.75 W, 20 Hz) for removal of the pocket-lining epithelium in periodontal pockets without causing necrosis or carbonization of the underlying connective tissue in vivo [39]. Yukna etal [40] reported that the laser assisted new attachment procedure could be associated with cementum-mediated new connective tissue attachment and apparent periodontal regeneration on previously diseased root surfaces in humans.

Furthermore, in an animal study the Er:YAG laser also seems to induce new cementum formation after pocket irradiation [41]. Thus, adjunctive or alternative use of laser treatment in periodontal pockets may promote more periodontal tissue regeneration than conventional mechanical treatment.

Studies evaluating the potential of the adjunctive application of a diode laser in the nonsurgical treatment of periodontitis have also recently been reported. The pulsed diode laser (805 nm) seems to produce a higher level of bacterial elimination from periodontal pockets than conventional scaling alone, especially with aggregatibacteractinomycetemcomitans [42].

Surgical pocket therapy

Laser application is effective in debriding areas of limited accessibility, such as deep intra bony defects and furcation areas where mechanical instruments cannot eliminate microbiological etiologic factors. Laser irradiation can facilitate complete debridement of the defect as a result of its ablation effect as well as improved accessibility when there is contact of the tip of the laser. The focused CO_2 laser can easily achieve degranulation of bone defects. CO_2 laser, when used with relatively low energy output in a pulsed and ⁄ or defocused mode, may provide root conditioning, detoxification and bactericidal effects on the contaminated root surfaces. Crespi et al [43] used the CO_2 laser in a defocused mode (13 W, 40 Hz) for the treatment of experimentally induced Class III furcation defects in dogs following flap surgery and reported that laser treatment promoted the formation of new periodontal ligament, cementum and bone. The Er:YAG laser has also been shown to be effective and easy to use for granulation tissue removal and root surface debridement during surgical procedures [44]. Sculean et al [45] reported that application of the Er:YAG laser during the treatment of periodontal intra-bony defects with access flap surgery is effective and safe with significant clinical improvements at six months following surgery, however, the laser treatment was equally effective as the mechanical debridement alone.

Osseous surgery

The use of erbium lasers is becoming increasingly popular for bone surgery. Erbium lasers in general offer more precision and better access than mechanical instruments. They reduce the risk of collateral damage, particularly when compared with rotary instrument that may become entangled with soft tissues.

Application of lasers in implant therapy

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 hemostasis, production of a fine cutting surface with less patient discomfort during the postoperative period, and favorable and rapid healing following abutment placement, thus permitting a faster rehabilitative phase [46]. Lasers were proposed for the treatment of peri-implant infections, based on their successful application with positive results as an adjunctive or alternative treatment for periodontal diseases. Some studies demonstrated that the Nd:YAG laser is contraindicated for use in the treatment of peri-implantitis because irradiation using this laser readily produced morphological changes such as melting, cracks and crater formation of the titanium surface [47] although A recent report showed its bactericidal effect with no damage to the titanium surface at low pulse energy [48].

With the CO2 laser, no morphological changes are observed on the implant surface. In addition, irradiation of titanium surfaces with the CO_2 laser does not influence osteoblast attachment [49]. Therefore, this laser is commonly applied for decontamination of implant surfaces [49,50]. The CO_2 laser is reported to be safe and to possess an ability to enhance bone regeneration when utilized for decontamination of implants in the treatment of experimentally induced peri-implantitis [51] and when clinically applied with beta-tricalcium phosphate in the treatment of peri-implantitis [52]. However, previous studies also indicate that there is a risk associated with the high temperature elevation of the titanium implant surface and carbonization of the adjacent bone tissue during irradiation with theCO2 laser [53].
Among the lasers applied in dentistry, the Er:YAG laser is considered to possess the best property for both degranulation and implant surface decontamination as a result of its dual actions of both soft and hard tissue ablation without causing thermal damage of the adjacent tissue.

PHOTODYNAMIC THERAPY

This is based on the principle that a dye which is a photosensitiser binds to a target cells and is activated by light of an appropriate wavelength.PDT has been used to treat localized microbial infections because free radicals that are formed during therapy might be toxic to bacteria [54].

LOW LEVEL LASER THERAPY (LLLT)

LLLT uses light source that generates pure light with single wavelength (InGaAlp,635nm). Biostimulatory effect of LLLT reduces discomfort, promotes wound healing, bone regeneration, suppresses inflammatory processes by inhibiting PGE2 and stimulates cellular ATP [55]. It also activates human gingival fibroblasts and cells to proliferate and release growth factors invitro .LLLT could promote new bone formation by inducing the proliferation and differentiation of osteoblasts and also increased the alkaline phosphatase activity and mRNA expression of osteoblastic differentiation markers like osteopontin, osteocalcin and bone sialoprotein. LLLT is a pro-oxidant in short term and anti oxidant in long term [56].

WOUND HEALING

There are numerous opinions regarding reduction in bacteremia, reduction in swelling, scarring, pain and faster healing response following laser surgical therapy. The assert of faster healing response appears to be wavelength specific and highly sensitive to energy density [8].

There are conflicting reports regarding healing of laser surgical wounds in comparison to that of conventional scalpel wound.All reports suggests that healing was equivalent for scalpel and Nd:YAG wound when laser was used at low power settings of 1.75W and 20HZ.

OCULAR HAZARDS

Potential injury to the eye can occur either by direct emission from laser or from the reflection from mirror like surfaces. Several structures of the eye may be injured as a result of laser emissions. The site of injury is directly dependent on the preferential absorption of various wavelengths by specific structures of the eye. The primary ocular injury that may result from a laser accident is a retinal or corneal burn. Other potential ocular injuries from various wavelengths may occur e.g., injury to the sclera, aqueous humor, cataract etc [58].

TISSUE DAMAGE

Laser induced damage to the skin and other non-target tissue (oral tissue) can result from thermal interaction of radiant energy with tissue proteins. Temperature elevations of 21ºC above normal body temperature (37ºC) can produce cell destruction by denaturation of cellular enzymes and structural proteins, which interrupts basic metabolic processes [58] of clinical significance is the potential damage to deeper tissue from penetration of specific wavelengths such as the continuous wave Nd: YAG laser.

Table 3: LASER HAZARDS ENCOUNTERED IN DENTISTRY [57]

LASER	WAVE LENGTH	WAVE FORM	DELIVERY TIP	ABSORPTION	APPLICATIONS
Argon	514nm	Gated or continuous	Flexible fibreoptic system	Pigment	Soft tissue incision ablation
Diode: combination of Gallium and other elements	635-980nm	Gated or continuous	Flexible fibreoptic tip contact mode	Pigment	Soft tissue incision Ablation Pocket debridement Flourescence calculus detection
Nd:YAG	1064nm	Free running pulse	Flexible fibreoptic tip contact mode	Pigment and dark substances	Soft tissue incision Ablation Pocket debridement
Er:YAG	2940nm	Pulsed	Water cooled fibreoptic system or hollow wave guide: contact mode	Water affinity for hydroxyapetite Hemostasis	Soft tissue incision Ablation Hard tissue use
Er,Cr:YSGG	2780nm	Pulsed	Sapphire crystal inserts, Contact mode	Scaling	Scaling Soft tissue incision Ablation Osteoplasty Ostectomy
CO2	10,600nm	Gated or continuous	Hollow wave guide	Water and hydroxyapetite Excellent hemostasis	Soft tissue incision Ablation De-epithelisation of gingiva during regenerative procedures Coagulation of donor site. Root conditioning

Respiratory/Environmental Hazards

These secondary hazards belong to a group of 'potential laser hazards' (also called as 'non beam hazards'). Inhaled air borne contaminants can be emitted in the form of smoke or plume generated through the thermal interaction of surgical lasers through tissue or through the accidental escape of toxic chemical and gases from the laser itself [59].

Combustion Hazards

Flammable solids, liquids and gases used within the dental surgical setting can be easily ignited if exposed to the laser beam. Toxic fumes released as a result of combustion of flammable materials present an additional hazard [60].

Electrical Hazards

Electrical hazards are grouped as:

● Shock hazards
● Fire hazards or explosion hazards

CONCLUSION

In this review we have discussed about the basic principles and applications of dental lasers. 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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