International Journal of Scientific and Technical Advancements

ISSN: 2454-1532

Performance of Lasers in Periodontal Therapy: A Comprehensive Review

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***Abstract*—**Periodontitis is a disease characterized by inflammation of gingiva that results in periodontal pocket formation with loss of the supporting periodontal ligament and alveolar bone around the teeth [1]. Periodontal treatment is divided into conventional procedures such as scaling, root planning and surgical procedures [2]. Surgical procedures are used to eliminate or regenerate the defects caused by the disease, but these procedures are time consuming and painful for the patients. In order to eliminate the disadvantages associated with scalpel methods, lasers have been introduced that can cut, ablate and reshape the oral soft tissues more easily, with no or minimal bleeding and minimal pain

***Keywords*—**Lasers: Periodontal disease.

I. Introduction

The development of periodontal disease and the methods used to treat them has undergone many changes from the past many years. The etiology for periodontal disease includes microbial components, host inflammatory responses, and host risk factors that contribute to the advancement of this disease. Bacterial plaque being the most important factor which triggers host response that results in inflammation and changes in the metabolism of the connective tissue and bone. 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. It is now accepted that periodontal disease is an infection and is opportunistic, the presence of virulent species of bacteria is as important as the host's response to them [1,2]. It becomes increasingly important to manage periodontal disease by addressing the microbes and the patient's health. Thorough treatment of periodontitis must be performed with the least amount of risk or side effects for the patient.

Soft tissue lasers are a good choice for bacterial reduction and coagulation in the treatment sequence [3]. The soft tissue lasers—argon (488 nm, 514 nm), diode (800–830 nm, 980 nm) and Nd:YAG (1064 nm)—are well absorbed by melanin and hemoglobin and other chromophores present in periodontally diseased tissues. The laser emits energy which is poorly absorbed by hydroxyapatite crystals but they are readily absorbed by water. The laser energy is delivered with a thin, flexible fiber optic system (300 to 400 μm in diameter) that allows the clinician to access the diseased tissue. The laser energy which is emitted by laser beam is directed in to the sulcus which is most attracted to and reactive with the inflamed tissue and pigmented bacteria.

Initial periodontal therapy includes nonsurgical debridement of tooth structure, local drug delivery, host modulation and reduction of sulcular bacteria with laser coagulation of the treatment site. Soft tissue lasers are used as an adjunct or an alternate in periodontal therapy to reduce the soft issue inflammation. It reduces the bacterial populations photo thermally and in addition eliminates the antimicrobial's problems like resistance, allergy and side effects, thus can be used even in children and pregnant women.

II. Use of Laser in Periodontal Therapy

A. NON SURGICAL

The initial and most important stage of periodontal therapy is non-surgical mechanical debridement of periodontally diseased root surfaces which involves removal of plaque, calculus, diseased pocket epithelium and necrotic cementum from the root surface.

In non-surgical therapy lasers can be used in following areas. [4, 5]

- Removal of calculus deposits and root surface irregularities.
- Removal of diseased pocket epithelium.
- Bactericidal effect of lasers on pocket organisms.

With the help of lasers excellent results can be achieved by ablating the tissues. Lasers can also produce strong bactericidal and detoxification effects, which are one of the most promising new technical modalities for nonsurgical periodontal treatment. Another advantage of lasers is that they can reach sites that conventional mechanical instrumentation cannot reach. Laser irradiation produce strong bactericidal and detoxification effects without producing a smear layer and the laser treated root surface may therefore provide favorable conditions for the attachment of periodontal tissue [1].

The appointment protocol for laser soft tissue therapy follows a simple formula for the 1-hour therapeutic appointment. The hard side of the pocket (tooth and root surface) is debrided first, followed by laser bacterial reduction and coagulation of the soft side (epithelial tissue) of the

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sulcus. For the initial appointment, the protocol includes the following:

- Anesthesia as needed (topical or injected).
- Ultrasonic scaler with antimicrobial irrigant.
- Hand instrumentation
- Laser bacterial reduction
- Laser coagulation of the treatment sites
- Postoperative instruction/home care instruction

An additional step is added to the appointment protocol in cases that require multiple visits.

Use of bactericidal dental laser in the periodontal pocket decreases the pathogenic microbial population, removes the diseased epithelial lining of the pocket and restores the tissues to health. For non-surgical periodontal therapy, it is important to use very low power settings. The purpose of this procedure is not to cut but to disinfect or decontaminate the tissue. When using a laser with fiber-optic delivery, such as Nd: YAG and diode, the laser fiber is placed into the pocket 1mm sort of the probing depth. For lasers without fiber-optic delivery, such as CO_2 lasers, the laser is placed at the entrance to the pocket. With the delivery system, the laser is walked around the pocket, in a manner similar to that used when measuring probing depths [6].

Fluorescence emission measurements on samples exhibiting calculus and dentin were performed. The fluorescence measurements revealed that calculus favourably absorbs wavelengths up to 420nm and that dentin is much less absorbing in that wavelength spectrum.

Histological investigations were performed on teeth extracted due to severe periodontitis and on freshly surgically removed impacted third molars. Light microscopic evaluations revealed that selective calculus removal is possible using a laser. The experiments revealed that dark colored sub gingival and light colored supra gingival deposits are easily removed. Moreover, experiments showed that bacteria laden microbial plaque could easily be removed with laser [7].

Mark Levin et al compared two techniques for removal of sub gingival calculus from root surfaces. The Er:YAG laser's ability and efficiency to remove sub gingival calculus was compared to the traditional manual curettage technique. The use of the Er:YAG laser as a modality for calculus removal seems promising and efficient [8].

Total calculus removal was demonstrated using electron microscopic studies at higher magnification in many studies. Whereas, Radvar et al [9] performed scaling and root planning using Nd:YAG laser at a low power level of 0.5 or 0.8 W in 80 periodontally affected sites of teeth scheduled for extraction in 11 patients. Scanning electron microscopy examination revealed that the low Nd:YAG laser energy levels did not cause any heat damage to the root surface but failed to improve clinical and microbiological parameters of periodontal disease as compared to scaling and root planning.

Tseng et al [10] demonstrated that partial removal and detachment of the calculus from the root surface was seen with the Nd:YAG laser. He noted melting of calculus and thermal change in localized areas of the original cementum and even dentin after irradiation at high power. Nd:YAG laser irradiation was performed at the calculus cementum interface. The integrity of the calculus root surface attachment was not affected at 1.5 W irradiation whereas 3 W irradiation detached the calculus without root surface damage similar to conventional hand instrumentation.

Anti-bacterial effect of laser revealed that lasers shows a greater reduction in sub gingival bacteria than that achieved by traditional therapy. Many laser bactericidal studies have been in vitro investigations that have little relevance to the protected biofilms of a periodontal pocket. Most laser bactericidal studies reported that a dose response relationship, that is increase in power or energy density results in increase destruction of bacteria. Current evidence show lasers, as a group, to be unpredictable and inconsistent in their ability to reduce sub gingival microbial loads beyond that achieved by SRP alone. Further, this conclusion also appears to apply to the use of photodynamic therapy, either as a mono therapy or adjunctive to SRP [11] .

B. SURGICAL

For most of the soft tissue surgical procedure, the laser is a viable alternative to the scalpel. Different wavelength of lasers can be used for different soft tissue procedures such as frenectomy, gingivectomy, gingivoplasty, de-epithelization, removal of granulation tissue, second stage exposure of dental implants, lesion ablation incisional and excisional biopsies of both and malignant lesion, irradiation of aphthous ulcers, coagulation of free gingival graft donor sites and gingival depigmnetation [12].

Lasers offer many advantages over steel surgical instruments, including a dry and bloodless surgery, reduced bacteraemia at the surgical site, reduced mechanical trauma, minimal post operative swelling and scarring and minimal post operative pain [6].

III. USE OF LASER IN FRENECTOMY

Frenectomy is a surgical procedure that involves removal of the frenum along with it's under lying attachment and may be required in the correction of an abnormal diastema between maxillary central incisors [13].

In the beginning of the 1990s the use of laser systems in periodontal therapy was limited to soft tissue procedure such as gingivectomy and frenectomy as application to periodontal hard tissue had previously proved to be clinically unpromising.

When frenectomy is performed via laser ablation, neither sutures nor surgical packing is necessary because the surgical site heals by secondary intention. The frenectomy reduces frenal strain and encourages the health of the gingiva [6].

IV. USE OF LASER IN GINGIVAL CURETTAGE

Gingival curettage is the removal of the inflamed soft tissue lateral to the pocket wall [13]. The conventional gingival curettage using mechanical instruments has been shown to have no advantage over routine scaling and root planning. Therefore, the present aim of periodontal therapy is to debride the root surface completely. However, the poor clinical

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outcome of gingival curettage may have been due to the lack of an effective tool for soft tissue debridement. The use of lasers in curettage shows excellent ablation of tissues along with rapid healing. This procedure might be more effective for the treatment of residual pockets after initial therapy and during maintenance, as the part of laser energy penetrates into periodontal pockets during irradiation. The attenuated laser at a low energy level might then stimulate the cells of surrounding tissue resulting in the reduction of the inflammatory conditions and reducing postoperative pain. Although there is no clear evidence to date that laser applications improve clinical outcome due to the action of curettage, laser treatment has a potential advantage of accomplishing soft tissue wall treatment effectively along with root surface debridement and should further be investigated [14].

V. Laser in Gingival Hyperpigmentation

Laser energy may be used to remove gingival hyperpigmentation and lighten tissue pigment. In many cultures, light colored gingiva is considered more esthetic. Because melanin, the primary pigment chromophore in gingiva, readily absorbs diode and neodymium- doped yttrium aluminium garnet (Nd: YAG) wavelengths, these lasers are ideal for pigment removal. However, some studies favour the Er family or CO_2 wavelengths, which easily ablate soft tissue because of the high water content of gingiva. Lasers can also be used for removal of abnormal gingival discoloration namely metal tattoos [15].

VI. Use of Lasers in Furcation and Osseous Defects:

The use of Nd:YAG laser along with conventional treatment for bacterial reduction has been studied by many authors. Nd:YAG laser irradiation associated with scaling and root planning in class II furcation defects has been done in many studies. Both conventional and laser assisted treatments resulted in improvements of most clinical parameters. But a significant reduction in the total bacteria counts was observed in Nd:YAG laser associated with conventional treatment group. There was significant reduction in bacterial counts in class II furcation immediately after irradiation, although this reduction was not observed 6 weeks post operatively.

Laser irradiation to the root surfaces was seen to be beneficial only in reduction of horizontal depth in treatment of Class II furcation defects. The addition of laser irradiation to the root surfaces was especially beneficial in treating deeper Class II furcation defects (initial horizontal probing depths ≥ 5 mm).

VII. Use of Laser in Clinical Crown Lengthening:

Certain carbon dioxide, Nd:YAG, argon, Ho:YAG, Er:YAG, Nd:YAP, Er,Cr:YSGG, diode and frequency-doubled Nd:YAG lasers have been cleared by the U.S. Food and Drug Administration for intraoral soft tissue surgery. Certain Er:YAG and Er,Cr:YSGG lasers have been cleared for osseous crown lengthening [16]. When crown lengthening is performed, a complete periodontal and radiographic examination must be performed including measurement of probing depth.

Aesthetic crown lengthening can easily be managed with lasers if clinically short crowns are the result of gingival overgrowth or lack of passive eruption. Lasers have remarkable cutting ability and they generate a coagulated tissue laser along the wall of laser incision which promotes healing. Other advantages include a relative bloodless operative field, minimum smelling and vaporization with much less post operative pain [17].

VIII. Use of Laser in Gingivectomy:

Gingivectomy means excision of the gingiva. There is increased visibility and accessibility for complete calculus removal and thorough smoothing of the roots, creating a favourable environment for gingival healing and restoration of a physiologic gingival contour [13].

Laser is also used as an alternative treatment. The laser gingivectomy appears to offer several advantages over the classic gingivectomy for the removal of hyperplastic gingiva and especially that of phenytoin hyperplasia. The advantages of using the CO_2 laser are, the laser offers an almost completely dry, bloodless surgery. This is due to the laser's ability to coagulate vessels 0.5 mm and smaller. Because of this dry field, surgical time may be reduced. There is the ability to coagulate, vaporize or cut by varying the power and the time of application. There is instant sterilization of the area, therefore decreasing the chances of bacteremia. There is non-contact surgery, thus no mechanical trauma to the surgical site, leading to minimal postoperative swelling. Postoperative pain appears to be greatly reduced[18]. CO_2 laser has been used for removal of phenytoin induced gingival growth and with minimal post operative discomfort and prompt nearing of gingival tissue [12].

IX. Role of Lasers in Vestibulplasty [19]

Vestibuloplasty is a surgical procedure which is done to deepen the shallow vestibule. Various surgical techniques such as Edlanplasty, Kazanjian vestibuloplasty and Corn's periosteal separation vestibuloplasty have been used to increase the vestibular depth. The conventional procedure has many disadvantages such as pain and post-operative discomfort.

To overcome the disadvantages of conventional procedure laser assisted vestibuloplasty has been employed. A laser assisted vestibular deepening was performed with minimal amount of local infiltration anaesthesia. The incision was very precise with reduction in treatment time as lasers permit better visualization of the surgical field by sealing the small blood vessels, thereby achieving good hemostasis by enhanced stimulation of factor VII for clotting, reducing the need for suturing.

Diode lasers with an effective penetration depth of 2 mm in the tissues, seal the small lymphatic vessels minimizing edema post surgically. The denuded periosteum in the Clark's vestibuloplasty procedure heals by secondary epithelialization delaying the wound healing. Though the use of a free gingival

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graft can speed up the healing process; it further increases the patient's morbidity due to a second surgical site. On the other hand lasers having an advantage of creating asepsis in the surgical field owing to the bactericidal effect of the diode laser. Laser also enhances wound healing by the formation of a denatured protein coagulum termed as laser "eschar" or "biological bandage". The protection of the wound from bacteria is done by this layer of protein coagulum. Laser group demonstrating better patient's perceptions and healing outcome with successful enhancement of the patient's vestibular depth. Though sound evidence based on further research validated by a bigger sample size and protocols are necessary. Lasers provides a good alternative option to scalpel in vestibuloplasty procedures.

X. Role of Lasers in Endo Perio Lesions: [20]

Endo-perio lesions can persist if not treated properly. For proper results an accurate diagnosis and correct treatment plan is necessary. Based on treatment plan, Grossman (1988) classified endo-perio lesion into 3 types: Type 1 - Requiring endodontic treatment only; Type 2 - Requiring periodontal treatment only and; Type 3 - Requiring combined endo-perio treatment. The satisfactory root canal disinfection by using rotary systems is studied by many authors. The role of laser in disinfection of the root canal has been demonstrated by many authors. The advantage of using high-power diode laser is that it reduces dentin permeability and does not cause the dentin melting which is a characteristic feature of neodymium laser. Pro Taper rotary file system was used for biomechanical preparation and soft tissue diode laser was used for disinfecting root canal. The use of a diode laser in soft tissue procedures becomes a choice of option because they have an affinity for hemoglobin and gingival pigments that makes the separation of soft tissue very precise and decontaminate the working area and also reduces postoperative swelling. Soft tissue diode lasers also have additional benefits like portability, affordability and ease of use. Acute trauma is the most cause for replacement resorption. Since less than 20% of the surface of root was involved, a new cementum formation and PDL attachment was seen due to the functional stimuli (transient ankylosis). The correct diagnosis and treatment planing of an Endo-Perio lesion is usually very difficult for the clinician. Therefore, it is essential that both endodontic lesion and periodontal lesion be managed individually and sequentially. Use of Soft tissue diode laser is an effective and less traumatic method than conventional treatment option. Such technological innovations present opportunities to provide flexible treatment options to patient while simultaneously enable clinicians to expand their level of skill. Furthermore, these procedures can be performed with minimal postoperative challenges and uneventful healing within a short period of time.

XI. Uses of Laser in Regenerative Periodontal Surgery:

The removal of diseased tissue from the surgical site determines the success or failure of the surgical procedure. The design, reflection and re-suturing of a full thickness mucoperiosteal flap for any surgical procedure is relatively straight forward, the flap base must be wider than the flap crest to ensure adequate blood flow. However, if the diseased soft tissue and calcified accerations on the root surface are not removed, the surgical procedure will not be successful. Many techniques and instruments are available, lasers are now being used for regenerative periodontal surgery [6].

Schwarz et al [40] showed that Er: YAG lasers are excellent tools that can promote periodontal regeneration by removing calculus from the root surface and ideal for successful attachment connective fibers. It was concluded that lasers alter the cementum surface in such a way that it makes it unfavorable for fibroblast attachment.

Rossmann et al used monkeys to determine the capability of the CO_2 laser to prevent epithelial migration after surgery involving soft tissue flap. Periodontal defects were bilaterally produced. Results showed that epithelisation of the CO_2 irradiated side was delayed by at least 7 days, allowing for new connective tissue to grow. The healing of connective was not retarded at all. The apical growth of the epithelium and this technique was less technically demanding and time efficient than other currently known method of epithelial retardation[6].

Israel et al used CO_2 laser in the human body. They performed open debridement and placed a notch at the crest of alveolar bone before closure. At re-entry 90 days later, non lased tooth developed a long junctional epithelium, the length of the root to the base of the notch on the lased side. The notch was filled with connective tissue and some repaired cementum [6].

The results of the CO_2 de epithelisation studies combined with Er: YAG studies of the effects of root surface lead to the conclusion that the most effective method of degenerative periodontal surgical technique. The Er: YAG laser would be used to debride the open surgical site, clean and disinfect the root surface and prepare the root surface for adhesion of fibroblasts. CO_2 laser would then remove the epithelium to allow the fibroblasts to adhere and proliferate, creating new attachment [6].

XII. LASERS IN DENTINAL HYPERSENSITVITY

Dentin hypersensitivity is the most common complain of patients in the dental clinics which is characterized by short, sharp pain arising from exposed dentin in response to stimuli typically thermal, evaporative, tactile, osmotic or chemical and which cannot be ascribed to any other form of dental defect or pathology [21]. Dentin hypersensitivity can arise through incorrect tooth brushing, gingival recession, inappropriate diet, and because of other factors. The sensation of pain is due to exposed dentinal tubules present on the root surface. Transmission of stimulus across dentin in hypersensitive teeth is due to the movement of fluid which is explained by hydrodynamic theory.

The laser treatment of dentin hypersensitivity controls pain both locally and centrally. Commonly used laser devices include low power-output devices such as helium-neon (He-

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Ne) (6 mw) and gallium-aluminum-arsenide (GaAlAs) (semiconductor) laser (30-100 mw) and intermediate power-output devices (0.3-10 w) such as Nd:YAG, CO_2, and Er:YAG lasers etc[22]

Compared to other lasers, the Nd:YAG laser beam penetrates deeply through dentin, bone, and non-pigmented soft tissues. Irradiation causing temperature rises exceeding the threshold of pulpal tolerance will cause thermal injury to the pulp. Previous studies have demonstrated that healthy pulp tissue is not injured thermally if the laser equipment is used at correct parameters so that any temperature rise within the pulp remains below 5°C. The Nd:YAG laser reduces the dentin hypersensitivity by occlusion or narrowing of dentinal tubules as well as direct nerve analgesia. In hypersensitive dentin, most dentinal tubules appears open and cause hypersensitivity. The Nd: YAG and co_2 effectively cause occlusion of these tubules[23].

Fig. 1. Tooth hypersensitivity with laser therapy

XIII. USE OF LASER IN IMPLANTS

Lasers can be used in implant dentistry in many ways [24]. Using lasers during soft tissue implant procedures offer the advantages of increased visibility due to hemostasis, greater ease in making incisions and contouring soft tissue, reduced bacteria at the surgical site and increased patient comfort due to minimal postoperative swelling and pain.

Several studies indicate that Nd:YAG lasers are contraindicated for implant surgery whereas diode, Er family and CO_2 lasers can be used for specific procedures such as removing soft tissue covering the integrated implant because Er and CO_2 laser are reflected away from metal surfaces, they only interact minimally with the implant.

Diode lasers were used in a study by Bach et al, who found a significant improvement in the 5-year survival rate when integrating laser decontamination into the approved treatment protocol. The decontamination of the implant surface is successfully seen in case of CO_2 laser. Kato et al found that this wavelength did not cause surface alteration, rise of temperature or serious damage of connective tissue cells located outside the irradiation spot or cause inhibition of cell adhesion to the irradiated area.

Nd:YAG by Block et al , which found that this wavelength did not sterilize the plasma-sprayed titanium or plasma-sprayed hydroxyapatite coated titanium dental implants that were used in the study. Kreisler et al performed a study on various wavelengths including Nd:YAG, Ho:YAG, Er:YAG, CO_2 and gallium-aluminum-arsenide for implant surface decontamination. At low power output Nd:YAG and Ho:YAG lasers are not suitable for decontamination of dental implant surfaces. To avoid surface damage the power output must be low in case of Er:YAG and CO_2 laser. The Ho:YAG laser seems to not cause any surface alterations. Block et al found that Nd: YAG laser did not sterilize the plasma sprayed titanium or plasma hydroxyapatite coated titanium dental implant. Successful treatment of peri-implant defects and re-osseointegration have been documented histologically after CO_2 laser irradiation as well as clinically with the CO_2 laser and the 980nm and 810nm diode laser [24].

XIV. USE OF LASER IN TREATMENT OF PERI IMPLANTITIS

Adherent bacterial plaque and calculus develop on the surface of the implant abutments as in natural teeth. Maintenance is required to keep the peri-implant tissue healthy in implant therapy lasers are used for decontamination of implant surface. The bactericidal properties of diode, Er and CO_2 lasers successfully treat periimplantitis. These lasers helped in removal of diseased, granulomatous tissue from periimplantitis sites as well as decontaminate implant surfaces and provide an environment favorable to osseous regeneration[6]. Aoki et al showed that Nd:YAG laser is not suitable for implant therapy since it easily ablates the titanium irrespective of output energy whereas diode laser does not interact with titanium or coated material.

XV. CONCLUSION

The use of lasers has become a topic of such interest and is a promising field in periodontal therapy. The results achieved following irradiation of biologic tissue by a specific wavelength of laser is directly related to the selected parameters. In other words, given the same wavelength, different laser parameters will yield different levels of energy density for periods of time and, thereby, different degrees of change in the target tissue.

Laser treatment is expected to serve as an alternative to conventional mechanical therapy in periodontics due to various advantages, such as easy handling, short treatment time, hemostasis and decontamination and sterilization effects. Regarding the laser apparatus, development of a new laser systems as well as improvements of currently available laser systems, such as miniaturization of device size and advances of performance, are required. Also, development of a new contact probe and hand piece suitable for periodontal treatment is necessary, as accessibility of contact probes into periodontal pockets is limited due to complex root morphology and furcated roots. The high financial cost of the laser apparatus is still somewhat prohibitory, and this has prevented the spread laser treatment among general practitioners. However, the price is expected to decrease with developments in laser technology and with increasing demand.

A laser is an expensive capital equipment purchase and dentists must do their own research to determine which laser wavelength and manufacturer will meet the needs of their practice, their patients and their pocketbook. With the

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ISSN: 2454-1532

development of thinner, more flexible and durable laser fibres, laser applications in dentistry is bound to increase. Based on this review of the literature, one must conclude that there is a great need to develop an evidence-based approach to the lasers for the treatment of periodontitis. Simply put, there is insufficient evidence to suggest than any specific wavelength of laser is superior to the traditional modalities of therapy. Finally science is the search for truth, and it is dynamic and constantly changing; in the regard, it is important that we keep on open mind to emerging technologies and apply therapies that are best for our patients.

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