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10.1515/bjdm-2016-0021

BALKAN JOURNAL OF DENTAL MEDICINE

BaSS

ISSN 2335-0245

Technology of Lasers and Their Applications in Oral Surgery: Literature Review

SUMMARY

The word "Laser" is an acronym for "Light Amplification by Stimulated Emission of Radiation". Recent advances in laser technology have brought a kind of revolution in dentistry. The purpose of this article is to provide an overview of clinical application of lasers in oral medicine and especially in oral surgery, including their advantages, disadvantages and safety.

Keywords: Lasers, dental application; Oral Surgery

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LITERATURE REVIEW (LR)
Balk J Dent Med, 2016; 20:131-137

Introduction

In ancient Greece, the exposure of the body to sun the sun was used in heliotherapy for the restoration of health. The Chinese used the sun to treat such conditions as rickets, skin cancer and even psychosis. This use of light for treatment of various pathologies is referred to as *phototherapy*.

Based on Albert Einstein's theory of spontaneous and stimulated emission of radiation, Theodore Maiman in 1960 introduced the first solid state ruby laser[1]. Shortly thereafter, in 1961, Snitzer[2] published the prototype for the Nd:YAG laser. The first application of a laser to dental tissue was reported by Goldman et al[3] and Stern and Sognnaes[4]. However, modern relationship of operative dentistry and laser takes its origins from an article published in 1985 by Myers and Myers[5], describing *in vivo* removal of dental caries using a modified ophthalmic Nd:YAG laser[4].

The introduction of lasers in the field of oral surgery has replaced a lot of routine surgical techniques and has resulted in several sophisticated products designed to improve quality of treatments.

Lasers are heat producing devices converting electromagnetic energy into thermal energy. The most significant and basic characteristic of them is wavelength, which defines the position of the laser in the electromagnetic spectrum. The wavelength used in medicine and dentistry generally ranges from 193 to 10.600nm, representing a broad spectrum from ultraviolet to the far infra-red range (Fig. 1).

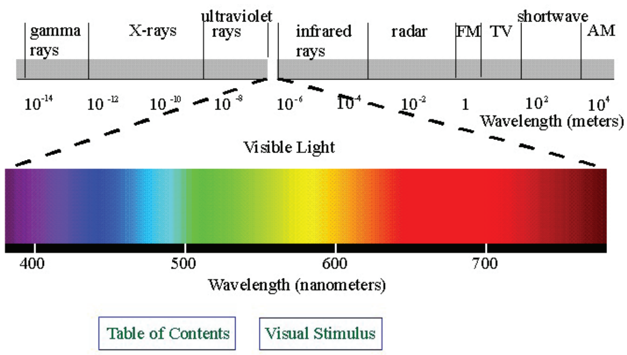

Figure 1. Electromagnetic spectrum

The absorption of the laser beam's energy plays an important role and is illustrated by the absorption spectrum for each laser wavelength in the targeted tissue. Apart from wavelength and absorption, reflection and transmission also play role in the interaction of laser with tissue. Transmission is the degree to which the laser's energy is able to penetrate into the tissue (Fig. 2).

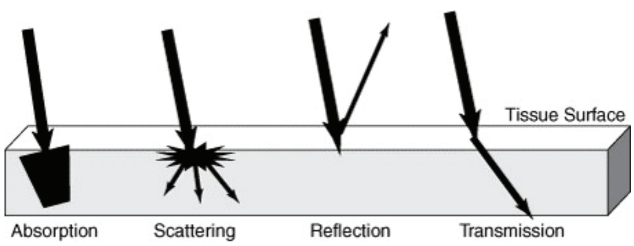

Figure 2. Laser/tissue interaction

The aim of this article is to provide an overview of main characteristics of lasers, their clinical application in dentistry, especially oral surgery, pointing to their advantages, disadvantages and safety.

Mechanism of Dental Laser Action

Light is a form of electromagnetic energy that behaves like a particle and wave. Its basic unit is photon.

- ***Laser Light*** - Laser light used for dental procedures has 4 features: (1) It is *monochromatic* (laser light is of one specific colour, thus of a single wavelength); (2) It is *coherent* (each wavelength is identical in physical size and shapes); (3) It can be *collimated* (photons can be collimated into an intensely focused energy beam that interacts with the target tissues); (4) It is *efficient*.
- ***Amplification*** (Fig. 3) - It is part of a process that occurs inside the laser. The inner part of laser, or the components of laser, are as follows: (A) *Optical cavity* - which is the centre of the device. Core of the cavity comprised of chemical elements, molecules or compounds is called active medium. It can be a gas, a crystal or a solid-state semiconductor; (B) *Two mirrors* - one at each end of optical cavity, placed parallel to each other. One mirror is reflective, which allows photons to be reflected back and forth to allow further stimulated emission. The other mirror is partially transmissive thus allowing light of sufficient energy to exit the optical cavity; (C) *Excitation sources* - either a flash lamp strobe device or an electrical coil, which provides energy into active medium; (D) *Cooling system*; (E) *Focusing lenses*; F) *Other controls*.

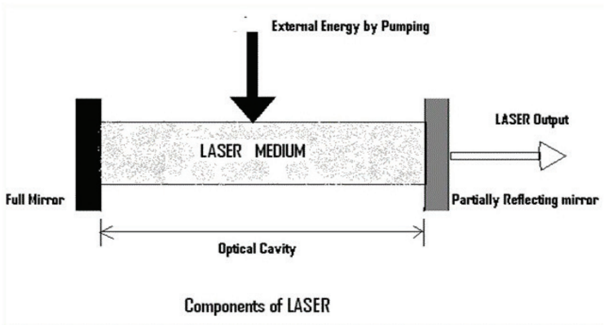

Figure 3. Laser Components

- ***Stimulated Emission*** - The smallest unit of energy is absorbed by the electrons of an atom or molecule (of the active medium), creating a short excitation; then a quantum is released, a process called spontaneous emission. The mirrors at each end of the active medium return the photons back and forth to permit the emission of the laser beam. Depending on how the laser active medium is energized, the laser photonic emission can occur inherently in a continuous wave (CW) or free-running pulsed (FRP) emission mode. CW means that energy is emitted constantly for as long as the laser is activated. A “gated” or “super-pulsed” laser is a variation of CW. The length of each pulse is called “pulse width” or “pulse duration”. On the other hand, FRP is a characteristic seen in lasers whose pulses have peak powers in the 1000w range.
- ***Radiation*** - refers to the light waves produced by laser as a specific form of electromagnetic energy[6,7]. The very short wavelength below approximately 300nm is called ionizing. Non ionizing radiations are those with wavelengths larger than 300nm and they have lesser frequency and less photon energy. They cause excitation and heating of tissues with which they interact. All dental lasers are non-ionizing.
- ***Tissue interaction*** (Fig. 4) - The action of lasers on dental tissues and bacteria depends on the absorption of laser by tissue chromophores (water, apatite minerals and various pigmented substances) within the target tissue. The principle action of laser energy on tissue is photo-thermal[8], and any mechanisms may be secondary to this process or may be totally independent. In general, lasers have four different interactions with the tissues. These are the following:

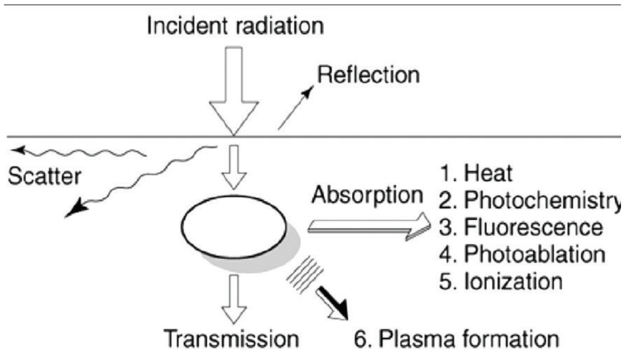

Figure 4. Laser/Tissue Interactions

1. Photo-thermal interaction (Tab. 1) - This occurs with high powered lasers. The radiant energy absorbed by tissue substances are transformed into heat energy, which produce the tissue effect[9].

Table 1. Target tissue effects in relation to temperature

Target tissue effects in relation to temperature

Tissue temperature (°C)	Observed effect
37–50	Hyperthermia
60–70	Coagulation, protein denaturation
70–80	Welding
100–150	Vaporization, ablation
>200	Carbonization

a. 37°C to 50°C - The tissue temperature is elevated but is not destroyed (hyperthermia).

b. 60°C - The tissue whitens or blanches. Proteins begin to denature without vaporization of the underlying tissue. This phenomenon is useful in surgically removing diseased granulomatous tissue, because if the tissue temperature can be controlled, the biologically healthy portion can remain intact.

c. 70°C - Produces desirable effect of haemostasis by contraction of the walls of the vessel and is used for coagulation.

d. 70°C to 80°C - The soft tissue edges can be welded together with uniform heating.

e. 100°C to 150°C - When the target tissue containing water is elevated to a temperature of 100°C, vaporization of the water within it occurs, a process called ablation. There is a physical change of the state; the solid and liquid components turn into vapour in the form of smoke or steam. As soft tissue is composed of a high percentage of water, excision of the soft tissue commences at this temperature. In hard tissues, ablation does not occur at this temperature, but the water component is vaporized and the resulting jet of steam expands and then explodes the surrounding matter into small particles. This mixture of steam and solid is suctioned away. This micro-explosion is termed "spallation".

f. >200°C - If the tissue temperature continues to be raised to about 200°C, it is dehydrated and then burned in the presence of air. Carbon, as the end product, absorbs all wavelengths. Carbonization occurs with risk of soft tissue damage. It can be because of high power setting or slow movement of fibre tip across tissue surface.

2. Photo-chemical interaction - The basic principle of photochemical process is that specific wavelengths of laser light are absorbed by naturally occurring chromophores, which are able to induce certain biochemical reactions.

3. Photo-mechanical interaction - This includes photo-disruption or photo-dissociation and photo-acoustic interactions. In photo-acoustic effects, the pulse of laser energy on the dental tissues can produce a shock wave. When this shock wave explodes the tissue, it creates an abraded crater.

4. Photo-electrical interaction– This includes photo-plasmolysis, which describes how the tissue is removed through formation of electrically charged ion[9].

- ***Energy density (Fluency)*** - Energy density is defined as energy (Joules) per square centimetre of spot size (J/cm^2). The laser beam spot size can be focused or defocused. Depending on the degree of beam focus, the laser beam spot size can be altered and fluency will accordingly change.

Classification of Lasers

Lasers used in dental practice can be classified into several categories according to: (1) the range of wavelength, (2) the lasing medium, such as gas laser and solid laser, (3) tissue penetration - soft tissue and hard tissue lasers, (4) The risk related to laser application, and (5) potential hazards.

Several types of laser are available based on the wavelengths, which can be used in oral surgery. The most commonly used nowadays are the following (Tab. 2):

Table 2. Types of lasers and their characteristics

Laser Type	Wavelength	Active Medium	Major Biological/ Chemical Absorbed
Alexandrite	377 nm	Solid	Calculus
Argon	488–515 nm	Gas	Hemoglobin
HeNe	632 nm	Gas	Melanin
Diode	812–1064 nm	Solid	Melanin, hemoglobin
Nd:YAG	1064 nm	Solid	Melanin, water, dentin
Ho:YAG	2120 nm	Solid	Water, dentin
Erbium	2790–2940 nm	Solid	Water, hydroxyapatite
CO_2	9.3,9.6, 10.6 nm	Gas	Water, hydroxyapatite

CO_2, carbon dioxide; HeNe, helium neon; Ho:YAG, holmium:ytrrium aluminum garnet; Nd:YAG, neodymium:yttrium aluminium garnet.

- ***CO_2 Laser*** (10,600nm wavelength, 5-15W) - The carbon dioxide laser is a gas-active medium laser and the light energy is placed at the end of the mid-infrared invisible non-ionizing portion of the spectrum. This is most commonly used in soft tissue periodontal and oral surgery. The CO_2 wavelength is 10.600nm and has a very high empathy for water. It is delivered through a hollow tube-like waveguide in continuous or gated pulsed mode[10]. It has the highest absorption in hydroxyapatite compared to other dental lasers (about 1000 times greater than erbium), but can lead to thermal damage if there is a contact with hard tissue[11]. It leaves a char layer on root surface. Some disadvantages are the high cost and the large size. CO_2 laser has a shallow depth of penetration into tissue and it is used ideally for soft tissue incision and ablation, sub-gingival curettage, superficial lesions and removal of sialoliths.

- ***Erbium Laser*** - The erbium "family" laser has two wavelengths:
- ***Er:YAG*** (yttrium aluminium garnet) laser - (2.940nm) - it has an active medium of a solid crystal of yttrium aluminium garnet that is doped with erbium[12];
- ***(Er,Cr):YSGG*** (yttrium scandium gallium garnet) laser - (2.780nm) - it has an active medium of a solid crystal of yttrium scandium gallium garnet that is doped with erbium and chromium. There is absence of melting, charring and carbonization. The absorption in water of this laser is two to three times lower than that of Er:YAG laser and their thermal effects on the tissue are much higher if not administered correctly.

The erbium wavelengths have a high empathy for hydroxyapatite and the highest absorption of water compared to other dental laser wavelengths. This is the preferable laser for treatment of dental hard tissue, but also, in contact mode with special surgical tips, it can be used to cut soft tissues. The benefits of treating patients with the erbium family of lasers include bactericidal effects, which can sterilize the area, and analgesic effect on the target tissues, similar to the Nd:YAG devices[13]. Also many studies have shown that the erbium laser energy applied to bone releases growth factors that enhance regeneration of bone[14]. In maxillary alveolar bone, the speed of laser is comparable with that of a bur and slightly slower in the mandible, reflecting the greater mineral density of cortical bone[15,16].

The difference between CO_2 and Er:YAG laser lies in their differing absorption coefficients: Er:YAG lasers are much more strongly absorbed in the water. On the other hand, CO_2 lasers show very high absorption on the tissue surface.

- ***Argon Laser*** - (488nm, 514nm wavelength, 1-20W power) - it is a laser with an active medium of argon gas that is energized by a high-current electrical discharge. It is fibre optically delivered with fibre diameter 300μm in continuous wave and gated pulsed modes. The light energy is placed in the visible spectrum. Argon lasers are readily absorbed by haemoglobin and melanin; thus, they have excellent haemostatic capabilities. These lasers are useful in the treatment of pigmented lesions, vascular anomalies and soft tissue incisions and ablations[17]. Neither wavelength is well absorbed in dental hard tissues or in water.
- ***Nd:YAG*** (Neodymium yttrium aluminium garnet laser) - (1064nm wavelength) - it has a solid active medium, which is a garnet crystal combined with rare earth elements yttrium and aluminium, doped with neodymium ions. The Nd:YAG with a very long pulse duration (between 90μs and 150μs) penetrates water up to 6mm depth before it is attenuated to 10% of its original strength. It belongs to invisible near-infrared portion of the electromagnetic spectrum. Energy is scattered rather than absorbed. The Nd:YAG laser is ideal for ablation of haemorrhagic tissue. It provides a relatively conservative procedure, which is related to rapid wound healing[18]. With Nd:YAG laser procedures anaesthesia is required in less than 50% of cases[19].

The wide-spread belief that Nd:YAG lasers have the highest penetration depths in the soft tissue is only partly correct. A study conducted at the RWTH Aachen[19] proved that a free-running pulse Nd:YAG laser has a penetration depth of approximately 0.1mm to 0.3mm, whereas a continuous wave mode Nd:YAG laser has a penetration depth of up to 6mm.

- ***Diode Laser*** - (range from about 800nm to 980nm wavelength, 1-10W power) - it is a solid active medium laser that includes semi-conductor crystals using some combination of aluminium or indium, arsenic and gallium. Due to crystalline nature, the ends of the crystal can be polished relative to internal refractive indices to produce totally and partially reflective surfaces. The light energy is placed at the starting of the near-infrared portion of the invisible non-ionizing spectrum. Each machine employs a flexible optic fibre (300μm diameter) to deliver the treatment beam to the desired area.

These lasers are said to be running in either CW or pulsed mode. Pulsing is achieved by electronically switching the laser on and off. With this method, the laser power in pulse is not increased, but is in the order of several Watts. In comparison, free-running pulse Nd:YAG laser systems, which can generate high peak powers, individual pulse powers can reach several thousands of Watts. Research has shown that diode laser is one of the most versatile with regard to the number of possible treatments options and can be effectively used in the field of soft tissue surgery[20]. In oral surgery, these machines can be used in numerous clinical procedures, such as various types of soft tissue surgery, second stage implant recovery, in peri-implantitis, sub-gingival curettage etc. There are many indications and researches, which show that diode laser can be used to perform these procedures with added bonus of disinfecting the treated area. But the most important benefits in comparison to all other types of laser are the ease of operation, the sub-millimetre dimension and their extreme compactness[21,22,23].

Generally, surgical procedures in soft tissue require a cautious approach. For instance, a 810nm diode and CO_2 lasers are very well suited for frenectomies (operations on the frenula of the lips, cheeks or tongue). Cautions is required when using Nd:YAG and 980nm diode lasers because the higher thermal effect of these wavelengths (<100μs) can very often cause necrosis.

Application of Lasers in Oral Surgery

There are plenty of soft and hard tissue procedures that can be performed with lasers in oral surgery.

Soft Tissue Clinical Applications

For many intraoral soft tissue surgical procedures, the laser is a viable alternative to the scalpel. The most popular and effective lasers nowadays for soft tissue procedures are CO^2, Nd:YAG and Diode lasers. There are many categories of soft tissue procedures that can be treated by lasers, such as gingivectomy and gingivoplasty, frenectomy, de-epithelialization of reflected flaps, depigmentation, measure blood flow-lesion ablation[24], second stage exposure of dental implants, sub-gingival debridement curettage[25], incisional and excisional biopsies of both benign and malignant lesions, removal of granulation tissue[26], coagulation of free gingival graft donor site, irradiation of apthous ulcers, removal of diseased tissue around the implants[27,28] etc.

Hard Tissue Clinical Applications

There are a number of surgical procedures in hard tissues that can be done by lasers, such as the removal of impacted teeth under bone, apicoectomies, osseous re-contouring, implant and bone osteotomies[29], bone grafting, jaw continuity defects, removal of inflammatory tissues around implants, crown lengthening, uncovering of permanent teeth for orthodontic purposes etc.

The erbium (Er) family of lasers can be the lasers of choice for the most of those procedures. Er lasers use extremely short pulse durations and can easily ablate layers of calcified tissue with minimal thermal effects. To date, alternative laser systems, including super-pulsed Nd:YAG, diode, CO_2, Ho:YAG etc. have not been proven so effective for use in hard tissue procedures.

Laser Advantages in Dentistry

The advantages of lasers in comparison to other conventional dental equipment are reported by various authors and include:

- Increased coagulation[30-35], yielding a dry surgical field for better visualization. This mechanism occurs when there is tissue absorption and controlled heat build-up. The warming of soft tissue more than 60°C will result in protein denaturation and coagulation[36], which are properties useful in haemostasis (Er lasers are the exception to this general statement, since they provide limited haemostasis)[37-39];
- Reduction in bacteraemia - Using lasers for surgical techniques can lead to tissue temperatures effective in reducing bacteria[39]. Studies have shown that combining photo-initiators with specific wavelengths can enhance bactericidal properties[40-45], and there are fewer risks of post-operative infections;
- Tissue surface sterilization;
- Faster healing response. Laser energy can aid healing through photo-bio-modulation;
- Decreased swelling, oedema and scarring[46,47];
- Reduced pain and discomfort after surgery[48]. Reports of pain relief mechanisms appear to originate in stimulating oxidative phosphorylation in mitochondria and through modulating inflammatory responses[49];
- Minimally invasive surgical procedures, compared to conventional techniques;
- Increased patient acceptance[50,51];
- Reduced surgical time.

Precautions Before and During Laser Surgery

Safety glasses are necessary for eye protection by all operatory personnel including the patient;

1. Protection of patient's throat and delicate oral tissues from accidental beam impact;
2. Use of wet gauze packs or towels to avoid reflection from shiny metal surfaces;
3. Adequate high speed evacuation should be used to capture laser plume, which is biohazard;
4. Speed of movement of the laser beam over the target tissue in order not to occur thermal damage - exposure of bone to heating at levels equal to or more than 47°C is reported to include cellular damage leading to osseous resorption. Temperature levels of equal to or more than 60°C result in tissue necrosis[52]. Additionally, if soft tissue temperature increases above 200°C charring and carbonization occur[53].
5. The clinician's awareness of safety control measures and hazards and the recognition of existing standards of care are significant points for dental practitioners to avoid complications and failures[54].

Conclusions

In conclusion, the application of laser, nowadays, involves habitual use of different procedures and dental devices. Laser technology seems to be a feasible and effective adjunct to conventional dental surgical techniques, showing many documented benefits and advantages in the clinician's daily practice. Lasers have significantly contributed to dental care in the 21st century, and are expected to become an essential component of contemporary dental practice in the near future. The advance of technology and knowledge of various applications in daily praxis will improve the use of laser and our understanding of the great spectrum of benefits regarding surgery and healing.

As Dr Theodore Maiman, the inventor of the first laser stated: "The medical application of the laser is fascinating for two reasons. It is optimistic mission on the one hand while, on the other, it counteracts the original impression of the laser being a death ray".

References

1. *Maiman TH*. Stimulated optical radiation in ruby. *Nature*, 1960; 187:493-494.
2. *Snitzer E*. Optical maser action of Nd (+3) in a barium crown glass. *Phys Rev Lett*, 1961; 7:444-446
3. *Goldman L, Hornby P, Meyer R, Goldman B*. Impact of the laser on the dental caries. *Nature*, 1964; 203:417.
4. *Stern RH, Sognnaes RF*. Laser inhibition of dental caries suggested by first tests in vivo. *J Am Dent Assoc*, 1972; 85:1087-1090.
5. *Myers TD, Myers WD*. In vivo caries removal utilizing the YAG laser. *J Mich Dent Assoc*, 1985; 67:66-69.
6. *Coluzzi DJ*. Fundamentals of dental lasers: science and instruments. *Dent Clin N Am*, 2004; 48:751-770.
7. *Convissar RA*. The biologic rationale for the use of lasers in dentistry. *Dent Clin N Am*, 2004; 48:771-794.
8. *White JM, Goodis HE, Tran KT*. Thermal laser effects on intraoral soft tissue, teeth and bone in vitro In: Proceedings of the Third International Congress on Lasers in Dentistry. International Society for Lasers in Dentistry. University of Utah Printing Services, Salt Lake City, Utah, 1993; pp 189-190.
9. Sebeena Mathew, Deepa Natesan Thangara. Lasers in Endodontics: JIADS 2010(Jan-March);Vol1(1):31-37.
10. *Pogrel MA, Muff DF, Marshell GW*. Structural changes in dental enamel induced by high energy continue wave CO_2 laser. *Laser Surgery Medicine*, 1993; 13:89-96.
11. *Fujiyama K, Deguchi T, Murakami T, Fujii A, Kushima K, Takano-Yamamoto T*. Clinical effect of CO_2 laser in reducing pain in orthodontics. *Angle Orthod*, 2008; 78:299-303.
12. *Van G*. Erbium lasers in dentistry. *Dent Clin N Am*, 2004; 48:1017-1059.
13. *Harashima T, Kinoshita J, Kimura Y, Brugnera A, Zanin F, Pecora JD, et al*. Morphological comparative study on ablation of dental hard tissue at cavity preparation by ER:YAG and Er,Cr:YAG lasers. *Photomed Laser Surg*, 2005; 23:52-55.
14. *Kesler G, Shvero DK,Tov YS, Romanos G. Platelet derived growth factor secretion and bone healing after Er:YAG laser bone irradiation. Journal of Oral Implantology. 2011;37(sp1):195-204.*
15. *Hibst R. Mechanical effects of erbium:YAG laser bone ablation. Lasers Surg Med 1992;12(2):125-130.*
16. Peavy GM, Reinisch L, Payne JT, Venugopalan V. Comparison of cortical bone ablations by using infrared laser wavelengths 2.9 to 9.2µm. Lasers Surg Med 1999;25(5):421-434.
17. Narang S, Maytreyee R, Singh N, Khare K, Jain P. Clinical application of soft tissue lasers in periodontics. Journal of Orofacial Research. 2015;5(3):94-98.
18. Romanos G, Pelekanos S, Strub JR. Effects of Nd:YAG laser on wound healing processes: Clinical and immunohistochemical finding in rat skin. Lasers in Surgery and Medicine 1995;Vol 16(4):368-379.
19. Gutknecht N. State of the art in lasers for dentistry. Journal of the laser and health academy Vol.2008;No3/1.
20. Das UK, Maiti N. Versatile diode. Journal of dental and medical sciences 2013; Vol 6, Issue1:01-06.
21. Goharkhay K, Mortiz A, Wilder-Smith P, Schoop U, Kluger W, Jakolitsch S, Sperr W. Effects on oral soft tissue produced by a diode laser in vitro. Lasers Surg Med 1999;25(5):401-406.
22. Walinski CJ. Irritation fibroma removal: A comparison of two laser wavelengths. Gen Dent 2004(May-June);52(3):236-238.
23. Adams TC, Pang PK. Lasers in Aesthetic Dentistry, Dent Clin North Am. 2004(Oct);48(4):833-860,vi.
24. *Ryden H, Bjelkhagen H, Soder PO*. Intrasulcular laser Doppler readings before and after root planning. *J Clin Periodontol*, 1995; 22:817-823.
25. Aoki A, Sasaki K, Watanabe H, Ishikawa I. Lasers in non-surgical periodontal therapy. Periodontology 2004;36:59-97
26. Williams TM, Cobb CM, Rapley JW, Killoy WJ. Histologic evaluation of alveolar bone following CO_2 laser removal of connective tissue from periodontal defects. Int J Periodontics Rest Dent 1995;15:497-506.
27. *Strauss R*. Lasers in oral and maxillofacial surgery. *Dent Clin N Am*, 2000; 44(4): 861-888.
28. *Kato T, Kusakari H, Hoshino E*. Bactericidal efficacy of carbon dioxide laser against bacteria-contaminated titanium implant and subsequent cellular adhesion to irradiated area. *Lasers Surg Med*, 1998; 23(5):299-309.
29. Nelson JS, Orenstein A, Liaw LH, Bern's MW. Mid-infrared erbium:YAG laser ablation of bone:the effect of laser osteotomy on bone healing. Lasers Surg Med, 1989; 9(4):362-374.
30. *Pick RM, Pecaro BC*. Use of the CO_2 laser in soft tissue dental surgery. *Lasers Surg Med*, 1987; 7(2):207-213.
31. *White JM, Goodis HE, Rose CL*. Use of the pulsed Nd:YAG laser for the intraoral soft tissue surgery. *Lasers Surg Med*, 1991; 11(5):455-461.
32. *Pedron IG, Ramalho KM, Moreira LA, de Freitas PM*. Association of two lasers in the treatment of traumatic fibroma: Excision with Nd:YAP laser and photobiomodulation using InGaAIP: A case report. *J Oral Laser Appl*, 2009; 9(1):49-53.
33. *Miyazaki H, Kato J, Watanabe H, Harada H, Kakizaki H, Tetsumura A, Sato A, Omura K*. Intralesional laser treatment of voluminous vascular lesions in the oral cavity. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 2009; 107(2):164-172.
34. *Genovese WJ, dos Santos MT, Faloppa F, de Sousa Merli LA*. The use of surgical diode laser in oral laser in oral hemangioma: A case report. *Photomed Laser Surg*, 2010; 28(1):147-151.
35. *Romanos G, Nentwig GH*. Diode laser (980nm) in oral and maxillofacial surgical procedures: Clinical observations based on clinical applications. *J Clin Laser Med Surg*, 1999; 17(5):193-197.

36. *Knappe V, Frank F, Rohde E*. Principles of lasers and biophotonic effects. *Photomed Laser Surg*, 2004; 22(5):411-417.
37. *Ishikawa I, Aoki A, Takasaki AA*. Potential applications of erbium:YAG laser in periodontitis. *J Periodontal Res*, 2004; 39(4):275-285
38. *Coluzzi DJ*. Fundamentals of lasers in dentistry: Basic science, tissue interaction and instrumentation. *J Laser Dent*, 2008; 16(Spec. Issue):4-10.
39. *Russell AD*. Lethal effects of heat on bacterial physiology and structure. *Sci Prog*, 2003; 86(1-2):115-137.
40. *Schultz RJ, Harvey GP, Fernandez-Beros ME, Krishnamurthy S, Rodriguez JE, Cabello F*. Bactericidal effects of the neodymium:YAG laser: In vitro study. *Laser Surg Med*, 1986; 6(5):445-448.
41. *Parker S*. Photodynamic antimicrobial chemotherapy in the general dental practice. *J Laser Dent*, 2009; 17(3):131-138.
42. *Meisel P, Kocher T*. Photodynamic therapy for the periodontal diseases: State of the art. *J Photochem Photobiol B*, 2005; 79(2):159-170.
43. *De Oliveira RR, Schwartz-Fiho HO, Novaes AB Jr, Taba M Jr*. Antimicrobial photodynamic therapy in the non-surgical treatment of an aggressive periodontitis: A preliminary randomized controlled clinical study. *J Periodontol*, 2007; 78(6):965-973.
44. *Prates RA, Yamada AM Jr, Suzuki LC, Hashimoto MCE, Cai S, Gouw-Soares S, Gomes L, Ribeiro MS*. Bactericidal effect of malachite green and red laser on Actinobacillus actinomycetemcomitans. *J Photochem Photobiol B*, 2007; 86(1):70-76.
45. *Chan Y, Lai C-H*. Bactericidal effects of different laser wavelengths on periodontopathic germs in photodynamic therapy. *Lasers Med Sci*, 2003; 18(1):51-55.
46. *Luomanen M, Meurman JH, Lehto V-P*. Extracellular matrix in healing CO_2 laser incision wound. *J Oral Pathol*, 1987; 16(6):322-331.
47. *Fisher SE, Frame JW, Browne RM, Tranter RMD*. A comparative histological study of wound healing following CO_2 laser and conventional surgical excision of canine buccal mucosa. *Arch Oral Biol*, 1983; 28(4):287-291.
48. *Haytac MC, Ozcelik O*. Evaluation of patient perceptions after frenectomy operations: A comparison of carbon dioxide laser and scalper techniques. *J Periodontol*, 2006; 77(11):1815-1819.
49. *Walsh LJ, Goharkhay K, Verheyen P, Moritz A*. Low level laser therapy. Chapter 13 in: *Moritz A, Beer F, Goharkhay K, Schoop U, Strassl M, Verheyen P, Walsh LJ, Wernish J, Wintner E*. Oral laser application. Berlin, Germany: Quintessenz Verlags GmbH, 2006; pp 521-539.
50. *Bader H*. Use of lasers in periodontics. *Dent Clin North Am*, 2000; 44:779-792.
51. *Wigdor H, Walsh J, Featherstone JDB, et al*. Lasers in dentistry. *Lasers Surg Med*, 1995; 16:103-133.
52. *Eriksson RA, Albrektsson T*. Temperature threshold levels for heat induced bone tissue injury: A vital microscopic study in the rabbit. *J Prosthet Dent*, 1983; 50:101-107.
53. *Miserendino LJ, Levy G, Miserendino CA*. Laser interaction with biologic tissues. Chapter 3 in: *Miserendino LJ, Pick RM* (Ed). Lasers in Dentistry. Chicago: Quintessence Publishing Co Inc, 1995; pp 39-55.
54. *Mason C, Hopper C*. The use of CO_2 laser in the treatment of gingival fibromatosis: A case report. *Int J Paediatr Dent*, 1994; 4:105-109.

Received on May 28, 2016.
Revised on July 28, 2016.
Accepted on August 30, 2016.

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