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# An Analysis of Laser in Dental Procedures

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**Abstract: -** Lasers were introduced into the field of dentistry as they are a precise and effective way to perform many dental procedures. Treatment with lasers provides a hope of overcoming the disadvantages of conventional dental procedures. As the applications for dental lasers expand, greater numbers of dentists will use the technology to provide patients with precision treatment that may minimize pain and recovery time. Every discipline of dentistry has been positively affected with the use of laser technology including oral medicine, oral surgery, pediatric and operative dentistry, periodontics and implantology, prosthetic dentistry. The ability of the lasers to perform less invasive procedures without any discomfort to the patients had made a tremendous impact on the delivery of dental care. This will continue as this technology will continue to improve and evolve.

**Keywords:** Argon, Dentistry, Fluorescence, Light amplification by stimulated emission of radiations, Wavelength neodymium-doped: yttrium aluminium garnet

## 1. INTRODUCTION

The word LASER is an acronym for light amplification by stimulated emission of radiation. The principle of the laser was the first known in 1917 when physicist Albert Einstein described the theory of stimulated emission.1 Lasers in dentistry are considered to be a new technology which is being used in clinical dentistry to overcome some of the drawbacks posed by the conventional dental procedures. This technology was the first used for dental application in the 1960s but its use has increased rapidly in the last few decades. Today, the lasers technology is used in the compact disc players, as a pointer for lecturer and above all in the medical and dental field. The use of laser technology and its advancements in the field of medicine and dentistry is playing a major role in patient care and well-being. This article intends a few topics such as laser history, laser-tissue interaction, lasers wavelength, types and applications of the use of lasers in various hard and soft tissue procedures in dentistry.

## 2. HISTORY OF LASERS

In 1960, Theodore Maiman was the first scientist who demonstrates the laser function and also developed a working laser device “known as ruby laser,” made of aluminum oxide, that emitted a deep red-colored beam. After this invention, dental researchers started investigating the various potentials of lasers. In 1965, Stern and Sognnaes reported that a ruby laser could vaporize enamel and had thermal effects on the dental pulp. In 1970’s, researchers began to find the clinical oral soft tissue uses of medical CO2 and neodymiumdoped: yttrium aluminum garnet (Nd:YAG) lasers. The first laser that had truly both hard and soft tissue application was the CO2 laser, invented by Patel in 1964,2 The Nd:YAG laser was also developed in 1964 by Geusic, a year after the invention of ruby laser, but it was largely overshadowed for a long time by the ruby and other lasers of the era until 1990, when the first pulsed Nd:YAG laser was released which is thought to have a better interaction with dental hard tissues. In 1971, The first use of lasers in endodontics was reported by Weichman and Johnson, as they utilize high power infrared CO2 laser to seal the apical foramen *in vitro*.2 Research continues for future indications with an all-tissue laser, including crown and veneer preparations, orthodontic applications, advanced new implant therapies including sinus augmentation and bone grafting, a gingival tissue resurfacing and even low-level laser therapy applications using the yttriumscandium-gallium-garnet (YSGG) laser. Since then, the clinical applications of the lasers continue to increase rapidly. At present, lasers are indicated for a variety of dental procedures which are discussed later.

## 3. LASER - TISSUE INTERACTION

Laser light has four types of interactions with the target tissue which depends on the optical properties of that tissue: Absorption, transmission of laser energy, reflection, scattering of the laser light.

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**3.1** ***Absorption***

When the laser is applied to the tissue, there is the absorption of laser energy in the target tissue. Different laser wavelengths have different absorption coefficients with the dental tissue components such as water, pigment, blood contents and mineral. Laser energy can be absorbed or transmitted based on the composition of target tissue. Those primary components are termed chromophores, which can absorb the laser light of specific wavelength. In general, the longer wavelengths, such as erbium laser has a greater affinity with water and hydroxyapatite. CO2 laser having wavelength of 10,600 nm is well absorbed by water and penetrates only to a few microns of the target tissue's surface.3 The shorter wavelengths ranging from 500 to 1000 nm are readily absorbed by the pigmented tissue and blood elements. For e.g., The pigment hemoglobin has greater affinity for argon laser while melanin absorbs diode and Nd:YAG laser. The primary determinant, which decides the depth of penetration and absorption of laser light in the target tissue, is the wavelength of the laser used. Depending on the wavelength used, some lasers able to penetrate the tissue deeper than others. In contrast, other laser has a limited penetration and has effect only on the tissue surface. For example, the Nd:YAG which is indicated for bone and hard tissue applications, penetrates 2-5 mm into tissue3 while CO2 laser has a limited penetration up to 0.03 to 0.1 mm in the tissue, thus indicated for soft tissue applications.

| Type of lasers | Wavelength (nm) pulse mode | Chromophores used | Target tissue |
|---|---|---|---|
| Diode | 850-1064 | Pigments<br>Hemoglobin<br>Melanin | Gingiva, mucosa |
| Nd:YAG | 1064 | Pigments<br>Hemoglobin<br>Melanin | Gingiva, mucosa |
| Er:YAG | 2940 | Water<br>Hydroxyapatite | Gingiva, mucosa, enamel, dentin, bone |
| Er, Cr:YSGG | 2860 | Water<br>Hydroxyapatite | Gingiva, mucosa, enamel, dentin, bone |
| $CO_2$ | 10640 | Water | Gingiva, mucosa, enamel, dentin, bone |

Table 1: Wavelength of laser light used and target tissue

**3.2** ***Reflection***

This property of laser causes laser light to redirects itself off the surface, having no effect on the target tissue. This reflected light could be dangerous when redirected to an unintended target such as eyes. However, a caries detecting laser device uses the reflected light to measure the degree of sound tooth structure.

**Classification of Lasers**

Gas lasers:
- Argon
- Carbon-dioxide

Liquid:
- Dyes

Solid:
- Nd:YAG
- Erbium: yttrium aluminum garnet (Er: YAG)
- Diode

Semiconductor:
- Hybrid silicon laser

Excimers:
- Argon-fluoride
- Krypton-fluoride
- Xenon-fluoride

**3.3** ***Scattering of the Laser Light***

There is also scattering of the laser light with correspondence decrease of that energy and possibly producing no useful biologic effect. This property can cause unwanted damage as there is heat transfer to the tissue adjacent to the surgical site. However, a beam deflected in different directions facilitates the curing of the composite resin or when treating an aphthous ulcer. The clinician must be aware of certain factors before applications of lasers such as appropriate laser wavelength, beam diameter, focused or defocused mode, pulse energy or power output, spot size, and tissue cooling. The result of using the smaller spot greatly increases the heat transfer from the laser to the tissue and a corresponding increased heat absorption in that smaller area. If the laser beam is allowed to diverged from the target tissue, this would results in the increase of the beam diameter and thus lessen the energy density of the laser beam. If a laser beam is allowed to strike the target tissue for a longer time, it will cause the tissue temperature to rise. This time can be regulated by the repetition rate of the pulsed laser emission mode as well.

**4.** ***Lasers Wavelength Used In Dentistry***

**4.1** ***Argon Lasers***

This laser has an active medium of ionized argon gas, energized by a high current electrical discharge, and the laser light is delivered fiber-optically in continuous wave and gated pulsed modes. There are two emission argon laser wavelengths used in dentistry: 488 nm (blue) and 514 nm (blue green). Both wavelengths are poorly absorbed in the enamel and dentin which is advantageous during cutting and sculpting gingival tissues as there is minimal interaction with the dental hard tissue without causing any damage to the tooth surface. Both wavelength is used as an aid for caries detection. When the argon laser light illuminates the tooth, the carious area appears as a dark orange-red color and is easily discernible from the surrounding healthy structures.3 Argon lasers are indicated in periodontics, as they possess bactericidal properties against *Prevotella* intermedia and *Porphyromonas gingivalis* and also used to treat vascular malformations such as a hemangioma. Potential complications of this laser treatment include granuloma formation, bleeding or non-resolution ofthe lesion.4,5

**4.2 *Diode Lasers***

The diode laser is manufactured from solid semiconductor crystals made from a combination of aluminum (with wavelength of 800 nm) or indium (900 nm), gallium and arsenic. These wavelengths penetrate deep into the mucosa and highly attenuated by the pigmented tissue, although hemostasis is slow as compared with the argon laser. These lasers are excellent soft tissue surgical lasers, so surgery can be performed safely as these wavelengths are poorly absorbed by the dental hard tissue. This laser is indicated for gingivoplasty, sulcular debridement and deeper coagulation process on gingival and mucosa. The chief advantage of the diode lasers is one of a smaller size, portable instrument. These lasers can also stimulate fibroblastic proliferation at low energy levels.6,7

**4.3 *Nd-YAG Lasers***

Nd:YAG has a solid active medium, which is a garnet crystal combined with rare earth elements yttrium and aluminum, doped with neodymium ions. The available dental wavelength of 1064 nm is indicated for various soft-tissue procedures such as cutting and coagulating of gingival and sulcular debridement. This laser provides good hemostasis provides a clear operating field during soft-tissue procedures. The laser is also indicated for the removal of incipient caries, although the working efficiency is less in comparison with the Er: YAG, or Er, chromium (Cr):YSGG lasers. When used in a noncontact, defocused mode, this wavelength can penetrate several millimeters which can be used for procedures such as treatment of aphthous ulcers or pulpal analgesia. However, due to a decrease in pulpal function, sometimes damage to the dental pulp can results.

**4.4 *The Erbium Family***

The wavelengths that are used are:
Erbium, Cr:YSGG (2780 nm)
Erbium, Cr: YSGG (2780 nm) which has an active medium of a solid crystal of yttrium scandium gallium garnet doped with erbium and chromium.
Erbium:YAG (2940 nm)
Erbium: YAG (2940 nm) which has an active medium of a solid crystal of yttrium aluminum garnet doped with erbium. Both lasers aid in caries removal. The laser produces clean, sharp margins during cavity preparation. Since, depth of penetration of laser wavelength is less, so pulpal damage is minimal. During caries removal, since the laser has an anesthetic effect, the analgesia is not routinely indicated in the majority of patients. The laser also assists in removal of endotoxins from root surfaces so providing an anti-microbial effect. These lasers are comfortable to the patients as vibration produces from the laser are less severe in comparison to the conventional high-speed drill. Thus, they are less likely to provoke intraoperative discomfort or pain.9,10

**4.5 *The Er-Cr:YSGG Laser***

This laser is widely indicated in restorative and etching procedures. During cavity preparation, the laser provides rough surfaces for bonding without causing any significant cracking in the dental hard tissue. The advantage of this laser for restorative dentistry is that a carious lesion in close proximity to the gingiva can be treated and the soft tissue recontoured with the same instrumentation. Furthermore, tissue retraction for uncovering implants is safe with this wavelength, because there is minimal heat transferred during the procedure. However, the rough surface produced during etching procedures will have a wide range of strengths of enamel bonds which is unreliable. Therefore, the procedure still requires acid etching to obtain equivalent bond strength.10

**4.6 *$CO_2$ Laser***

The CO2 laser is water or air cooled gas discharge, containing a gaseous mixture with CO2 molecules, that helps in producing a beam of infrared light. The light energy, whose wavelength is 10,600 nm, well absorbed by water and is delivered through a hollow tube-like waveguide in continuous or gated pulsed mode. The laser wavelength can easily assists in cutting and coagulation of soft tissue, thus providing a clear operating field. The laser is indicated for the treatment of mucosal lesion, since it has a limited penetration depth. Post-operative pain usually is minimal to none as it reduced pain by inducing local neural anesthesia as a function of neuron sealing and decreased pain mediator release. CO2 laser also has some disadvantages. However, there is delayed wound healing for a few days, as a result of delayed re-epithelization and a different pattern of wound contraction. Furthermore, the loss of tactile sensation could pose a disadvantage for the surgeon, but the tissue ablation can be precise with careful technique.

## 5. USE OF LASERS IN DENTINAL HYPERSENSITIVITY (DH) AND PAIN MANAGEMENT

**DH** is one of the most common causes of dental pain. A low level laser therapy (LLLT) has also been used for the treatment of DH. This relies upon laser-induced changes to neural transmission networks within the dental pulp, rather than alterations to the exposed dentine surface, as is the case with other treatment modalities. It has been suggested that LLLT may elicit descending inhibition in the central nervous system, in addition to local effects on nerve conduction, although this has yet to be proven.12 Low-power lasers inhibit the release of mediators from injured tissues. In other words, they decrease concentration of chemical agents such as histamine, acetylcholine, serotonin, $H^+$ and $K^+$, all of which are pain mediators. Low-power lasers inhibit concentration of acetylcholine, a pain mediator, through increased acetylcholine esterase activity.

## 6. USES OF LASERS ON HARD TISSUES

### 6.1 *Lasers for Caries Detection*

This diagnostic technology in which a Diagnodent, a 655 nm diode laser, aids in the detection of incipient caries is called laser-induced fluorescence. When the laser irradiates the tooth, the light is absorbed by organic and inorganic substances present in the dental tissues, as well as by metabolites such as bacterial porphyrins. These porphyrins showed some fluorescence after excitation by red light. Since bacteria are present in the carious lesions, carious tissue exhibits more fluorescence as compared to the healthy tissue which distinguish between the carious and sound tooth structure. It can detect occlusal, interproximal carious lesion or identify occult lesions beneath fissure sealants. Although, the procedure is considered to be safe, further studies are required for explorations the beneficial effects of this innovative technology.13-15

### 6.2 *Lasers for Caries Removal and Cavity Preparation*

The Er:YAG lasers are proven to be safe and effective in caries removal and cavity preparation in pediatric and adults patients without significant damage to tooth structure or patient discomfort. This device also aid in removal of defective composite restoration and ablate the distal carious lesion while a tunneling technique (in which the laser's sapphire tip was angled directly toward the distal carious lesion), thus preserving the tooth's distal marginal ridge.16,17 The principle used is fluorescence. As the laser is targeted to the tissue, bacteria present in the infected dentin provides signal to the clinician and could also control the action of a pulsed laser to achieve automated caries removal.

### 6.3 *Lasers Used for Calculus Removal*

The Er:YAG laser is used for calculus removal as the bacterial porphyrins in dental calculus give a strong fluorescence signal, which can be used to control lasers used for scaling. These lasers are effective in removing lipopolysaccharides and other root surface endotoxins and are highly bactericidal against certain periodontal pathogens including *P. gingivalis* and *Actinobacillus actinomycetemcomitans*.

### 6.4 *Laser Assisted Bleaching*

The objective of laser bleaching is to achieve the ultimate power bleaching process using the most efficient energy source while avoiding any adverse effects. Using the 488-nm argon laser as an energy source to excite the hydrogen peroxide molecule offers more advantages than other heating instruments. The argon laser rapidly excites the already unstable and reactive hydrogen peroxide molecule; the energy then is absorbed into all intermolecular and reaches eigenstate vibrations. Lasers can enhance bleaching by photo-oxidation of colored molecules in the teeth or by interaction with the components of the bleaching gel through photochemical reactions. The result is a visually whitened tooth surface.18

### 6.5 *Surgical Procedures*

Many different laser wavelengths have been used in Oral and maxillofacial surgery. Since there is excellent absorption of $CO_2$ laser at wavelength of 10,600 nm in the water-based tissues, it is widely indicated in oral surgical procedures performed intraorally and extraorally. $CO_2$ lasers make relatively deep and precise incisions and thus excellent hemostasis. There is less traumatic bone cutting with the use of Erbium lasers resulting in postoperative discomfort to the patients. The management of patients with sleep apnea, TMJ derangements, dental implants, premalignant lesions, and post-traumatic facial scarring has improved significantly with the advent of laser surgery. In a Clinical trial, 250 patients were treated with $CO_2$ lasers for conditions like gingival hyperplasia, benign and malignant lesions, red and white lesions and bleeding, and coagulation disorders. The results showed concluded that CO2 laser provides a bloodless field, less post-operative discomfort, tissue coagulation and better accessibility in some areas of oral cavity compared to conventional scalpel surgery. The advantages compared to scalpel wounds also included site-specific wound sterilization; minimal intraoperative trauma and subsequent less post-operative swelling, suturing is not required in most of the cases, minimal use of local anesthesia and less post-operative pain, discomfort, and better patient acceptance.19 Bone Surgery and Osseous Crown Lengthening The YSGG laser was also the first cleared for bone, including cutting, shaving, contouring and resecting oral osseous tissues. The laser was later cleared for osteoplasty, ostectomy, and osseous recontouring to correct defects and create physiologic osseous contours necessary for ideal clinical results. In 2003, the YSGG laser was the first laser device cleared for osseous crown lengthening to achieve biologic width which can be completed without laying a flap, suturing, or damage to the bone (Wang, 2002). The ease of use of the YSGG system provides the dentist with a strong ROI by performing the most of their own osseous crown lengthening procedures, which is important in an era fueled by prime time “extreme” dental makeovers, and growing demand for aesthetic dentistry.

## 7. USES OF LASERS ON SOFT TISSUES

### 7.1 *Laser Curettage*

Both the Nd:YAG and diode lasers are indicated for curettage. Laser assisted curettage significantly improves outcomes in mild to moderate periodontitis. The treatment is not invasive and comfortable to the patients. The beneficial effects of these lasers are due to the bacterial properties particularly against periodontal pathogens such as *A. actinomyc etemcomitans* and *P. gingivalis*. However, recent studies have shown that there are no added advantages of these lasers as compared with the conventional debridement.

### 7.2 *Laser Assisted Incisional and Excisional Biopsy*

These procedures are accomplished at 100°C. The lasers are placed in cutting or focused mode, held perpendicular to the tissue and follow the surgical outline. When laser light interact with the soft tissue, there is vaporization of intra and extracellular water content resulting in ablation or removal of biological tissue. However, when the temperature exceeds 200°C, there is heat generated within the tissues during the results in carbonization and irreversible tissue necrosis. In addition, there are specific soft tissue indications for the clinical use of lasers, including gingival depigmentation, gingivectomy/gingivoplasty, operculectomy, sulcus debridement, pre-impression sulcular retraction, laser assisted new attachment procedures, removal of granulation tissue. Pulp capping, pulpotomy and pulpectomy, incisions and draining of abscesses, removal of hyperplastic tissues, frenectomy, vestibuloplasty,and treatment of herpetic and recurrent aphthous ulcers. Other excisional procedures that can be easilyperformed using lasers are the removal of benign growths such as fibromas or papillomas. In addition, LLLT is indicated for oral soft tissue lesions such as frictional keratosis, nicotinic stomatitis, leukoplakia, erythroplakia, verrucous carcinoma.20 It has been shown that Er-Cr:YSGG (Waterlase C-100) system is used to release the fibrotic bands of oral submucous fibrosis. It works on “hydro-photonic process” in which the energy from the Er-Cr: YSGG laser interacts with water droplets on the tissue to create water molecule excitation, micro expansion and propulsion giving a clean and precise hard-tissue cutting.

### 7.3 *Photodynamic Therapy*

A more powerful laser-initiated photochemical reaction is photodynamic therapy (PDT), which has been employed in the treatment of malignancies of the oral mucosa, particularly multifocal squamous cell carcinoma. As in photo - activated dye, laser-activation of a sensitizing dye in PDT generates reactive oxygen species. These in turn directly damage cells and the associated blood vascular network, triggering both necrosis, and apoptosiss.21 PDT destroy the bulk of tumor cells, there is accumulating evidence that PDT activates the host immune response, and promotes anti-tumor immunity through the activation of macrophages and T lymphocytes. Clinical studies have reported positive results for PDT treatment of carcinoma *in-situ* and squamous cell carcinoma in the oral cavity, with response rates approximating 90%. The treated sites characteristically show erythema and edema, followed by necrosis and frank ulceration. The ulcerated lesions typically take up to 8 weeks to heal fully, and supportive analgesia is required in the first few weeks. Other than short-term photosensitivity, the treatment is tolerated well.

### 7.4 *Lasers in Pediatric Dentistry*

Treatment with lasers is beneficial when used in children as there is precise and selective interaction of lasers with the soft tissue. All procedures previously discussed are treated in the same manner in the p Pediatric population as well. Lasers can provide treatment without the need for needles and high-speed hand pieces causing less intra and post-operative discomfort to the children. Furthermore, there is less need for behavioral management therapies in case of lasers assisted therapy. During laser treatment, hemostasis can be achieved without the need of sutures in many patients. The Table 2 summarizes the type of lasers used in different specialties of dentistry.

## 8. LIMITATIONS OF LASERS

- It requires additional training and education for various clinical applications and types of lasers.
- High cost required to purchase equipment, implement technology and invest in required education.
- More than one laser may be needed since different wavelengths are required for various procedures.

Table 2: Laser applications in dentistry

| Application | Possible laser types |
|---|---|
| Basic research | All types |
| Laser tissue interaction | |
| Oral medicine | He Ne, diodes |
| Laser doppler flow metry | He Ne, diodes |
| Laser induced fluorescence (caries diagnosis) | Diode |
| Photodynamic therapy (for treatment of oral cancer) | |
| To release fibrotic bands in OSMF | ErCr:YSGG |
| Oral soft tissue lesions frictional keratosis, leukoplakia, verrucous carcinoma) | Diode |
| Oral and maxillofacial surgery | |
| To achieve hemostasis | $CO_2$ |
| Tuberosity reduction, alveoloplasty, bone and flap removal | Erbium |
| Conservative dentistry | $CO_2$, Nd:YAG, Er:YAG, |
| DH | |
| Cavity preparation | Diode |
| Composite resin light curing | $CO_2$, Nd:YAG, Er:YAG |
| Tooth surface conditioning, removal of defective composite restoration | Argon, Er:YAG |
| Endodontics | Nd:YAG, $CO_2$ |
| Root canal treatment, apicoectomy | $CO_2$, Nd:YAG |
| Periodontics | |
| Laser-assisted curettage | Nd:YAG, diode |
| Gingivectomy and gingivoplasty | $CO_2$ |
| Analgesic effect and bio-stimulation | |
| Stimulation of wound healing | He Ne, diodes, Nd:YAG |

## 9. CONCLUSION

The use of laser technology has been widely used in dentistry. When used efficaciously and ethically, lasers have been an essential tool in many dental treatments. However, lasers have got its own limitations. It has never been the "magic wand" in medicine and dentistry. The futures of laser dentistry are bright as further researches are going on. The emergence of lasers for various applications in dentistry may influence the treatment planning of patients. Lasers can also prove to be blessing in disguise if not used safely and properly. As Aaron Rose Says, "In right light at right time everything is extraordinary

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