

# Lasers: A Review With Their Applications in Oral Medicine



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## Abstract

Lasers in dentistry began to gain popularity in the 1990s. Lasers in dentistry are used as a treatment tool or as an adjunct tool. By using the laser in the field of dentistry, the main goal is to overcome the disadvantages, which are currently being experienced in conventional dental treatment procedures. Many specialties in dentistry including oral surgery, implants, oral medicine, periodontics, pediatrics, and operative use the current new laser technology. The ability of lasers to provide minimally invasive procedures with less discomfort to the patient has been useful in the patient delivery system in dental practice. This article describes in brief on the uses of lasers in oral mucosal lesions.

**Keywords:** Laser dentistry; Oral mucosal lesions; Dental lasers.

## Introduction

LASER is an acronym of light amplification by stimulated emission of radiation.<sup>1</sup> Lasers are intense beams produced by stimulated emission of radiation from a light source.<sup>2</sup> Einstein identified that a laser is promoted by the emission of radiation as a natural process. When a beam of light passes through a specific medium causing stimulation of the atoms within the medium to transfer the light in a specific direction, that is, the same direction as the medium by the same wavelength as that of the original beam, a laser beam is created. Lasers are capable of increasing light intensity to synthesize beams of an effective wavelength, which are directional and of a high intensity<sup>1</sup>. Albert's theory of spontaneous & simulated emission of radiation describes three characteristic features of lasers as follows: monochromatic, i.e. all the waves have the same energy and frequency; coherent, which describes all the waves of light to be in phases related to each other in speed and time; and collimated ensuring parallelism of the waves (low beam divergence).<sup>2</sup>

## History of Lasers

"Heliotherapy" was the practice followed by our ancestors, following which the development of action therapy and photomedicine took place. The award of the Nobel Prize to Finsen in 1903 for the development of the carbon arc lamp with lenses and filters for the treatment of diseases (especially lupus vulgaris) was a major milestone in the

development of lasers for medical use. Leon Goldman, a pioneer in laser medicine, have reported the biomedical aspects of lasers and have also recorded findings in laser dentistry, mainly on the effects of lasers on dental caries, teeth and other tissues since 1963.<sup>1</sup>

In 1917, Albert Einstein set the foundation for the invention of the laser by explaining the photoelectric amplification, and it was introduced to the public in 1959.<sup>3</sup> Miaman was the first person who used the laser in 1960 on the hard and soft tissue. Advancements in the application of lasers over the last two decades have extended their use in caries prevention, bleaching, cavity preparation, dentinal hyper-sensitivity, growth modulation as well as for diagnostic purposes. In the soft tissue, it has been used in wound healing, the removal of hyperplastic tissue to uncover impacted or partially erupted tooth, photodynamic therapy of malignancies, and photostimulation of herpetic lesion. It has been discovered that lasers have increased the efficiency, specificity, ease, cost, and comfort of dental treatment.<sup>4</sup>

In the early 1960s, it was noted the use of medical lasers in dental applications had limited application. In the early decades, the physicians realized that the light allowed them to observe many things such as skin color and wounds, and it helps them in choosing the most effective therapeutic course of action. This led researchers to explore the specific applications of lasers in the medical and dental fields.<sup>1</sup>

In the mid-1960s, enhanced methods of caries removal were reported, performed by an effective interaction of laser energy with tooth structure. Ruby lasers were very useful in vaporizing caries but they caused irreversible necrotic changes in the pulp tissue because of the high energy densities. Then, the Erbium Laser wavelengths were discovered, which did better in terms of the cavity preparation without damaging the pulpal tissue. Argon lasers were found to be effective in the photopolymerization of dental composites and Nd:YAG (neodymium-doped yttrium aluminum garnet) lasers were effective in various endodontic therapies, prosthetic devices, gold alloys, and prosthetic devices.<sup>5</sup>

In 1990, the Food and Drug Administration (FDA) approved the use of laser therapy in intraoral gingival and mucosal tissue surgery as it ensured a wound without suture, pain, and bleeding and increased the convenience for the dentist. The first laser designed specifically for the dentistry was introduced in the United States on May 3, 1990, by Myers. Among the various special lasers designed to be used for soft tissue procedures and for the teeth and bone, it has been seen that the erbium wavelength is very safe and effective. Lasers, either in therapeutic or photobimodulation, have shown effective results in healing. The first clinical results of photo-activated disinfection also showed good applications for disease control.<sup>3</sup>

### Classification of Lasers

Lasers in dentistry can be classified according to various factors, including the lasers active medium such as gas, liquid, solid and semi-conductor, which specifies the type of laser beam that will be emitted (Table 1). Invariably they can be also classified according to the lasing medium used as a gas laser and a solid laser. Furthermore, they can be classified according to tissue applicability in hard and soft tissue lasers or according to the wavelengths and the risk associated with laser application.<sup>4</sup>

The first gas laser was the helium neon laser which was promoted by a green wavelength and several infrared wavelengths. Carbon dioxide, NdYAG, and Er:YAG (erbium-doped yttrium aluminium garnet) categorised as Hard lasers can be used for both hard and soft tissue application but they have limitations as they are expensive and cause thermal injury to the tooth pulp. Cold lasers, also known as soft lasers, which are based on the diode device are compact and have low costs. These are commonly termed as low-level laser therapy (LLLT). The mixture of some noble gases such as argon, krypton, and xenon with reactive gases produce a special type of gas

discharge which is called the excimer laser. One of the most powerful lasers is the carbon dioxide laser which transfers energy to CO<sub>2</sub> molecule; this may convert electric power to laser output power. Neodymium has shown increased efficiency in laser species, when mixed with either yttrium-aluminium-garnet (YAG) or glass materials.<sup>6</sup>

The carbon dioxide laser is hydrophilic, has rapid soft tissue removal and haemostasis with shallow depth penetration and has maximum absorbency, although its bulkiness, high cost and destruction of hard tissue are to its disadvantages. Besides having good haemostasis, the Nd:YAG laser is highly absorbed by the pigmented tissue, keeping it very effective in surgical cutting and coagulation of the soft tissue. Moreover, it has been recorded that it can be used in periodontal disease control.<sup>4</sup>

The erbium laser has two wavelengths, the Er,Cr:YSGG (yttrium scandium gallium garnet) laser and the Er:YAG laser. The high affinity for hydroxyapatite and the highest absorption of water render it the best choice for treatment of hard tissues as well as soft tissue ablation that has a high percentage of water. The diode laser is primarily absorbed by tissue pigment and haemoglobin. On the other hand, it is poorly absorbed by hydroxyapatite and water. Hence, it has been used in aesthetic gingival recontouring, the removal of inflamed and hypertrophic tissue, soft tissue crown lengthening, frenectomies and photo-stimulation of aphthous, and herpetic lesions.<sup>4</sup>

LLLT is a recently developed technique with applications in medicine, dentistry, and physiotherapy. It can offer such therapeutic effects as accelerated wound healing and pain relief to patients. It is the application of laser light energy to living tissues to generate biosimulation effects without causing an excessive rise in temperature. The primary benefit is that it is a non-surgical technique, which will reduce the incidence of oedema and inflammations. The helium neon or cold lasers are applied to the tissues in continuous wave emission with a non-contact mode to generate the bio simulative effect. Improvement in wound healing, remodelling, and repair of bone, restoration of neural functions post injury and promotion of modulation of immune systems and nociceptive signals are the advantages associated with the use of soft lasers.<sup>1</sup>

LLLT has established itself well in clinical dentistry, attributed to the therapeutic effects like bio stimulation, regenerative capacity and anti-inflammatory effects seen at the lower heat. The diode laser has a wavelength range of 635 to 950 nm utilizing flexible quartz fibre and it is absorbed by the pigmentation of the soft tissue and has

**Table 1.** Classification of Lasers

Gas lasers	Liquid	Solid	Semiconductor	Excimers
-Argon -Carbon-dioxide	-Dyes	- NdYAG - Er:YAG -Diode	-Hybrid silicon laser	-Argon-fluoride -Krypto-fluoride -Xenon-fluoride

good haemostatic agent, the power output of which is 2 to 10 W.<sup>2</sup>

In surgical third molar extractions, LLLT regulates the inflammatory process causing lesser or no side effects by the reduction in pain and swelling and by the repair of destructed tissues because these complications are common in all patients after the removal of the third molar. It has shown the benefits in postoperative symptoms of impaction. LLLT nowadays is being used for many types of disorders. Recently, there has been a surge in the randomised controlled trials which focus on the effect of LLLT on various factors like wound healing, scarring, temporomandibular joint problems, oral mucositis, and dental pain. Other types were the argon ion and the krypton ion which have provided a lot of visible and ultraviolet laser wavelengths.<sup>7</sup>

LLLT has absolute contraindications in patients with coagulation disorders because it has a direct effect on blood flow and in cases of malignancies because it stimulates cell growth. The FDA classifies low-level lasers into low-risk devices because it is not harmful. The therapeutic laser is less than 500 mW.<sup>1</sup>

Currently, there are a lot of laser wavelengths that are used in dentistry, specifically oral surgery, including CO<sub>2</sub>, Argon, Nd YAG, KTP that are applied in various specialties in dentistry including the caries diagnosis and removal, light curing of the composite, control of bleeding in vascular lesions. Furthermore, they have been used in the temporomandibular joint surgery, the activation of tooth bleaching solutions, and the soft tissue procedures, for example, gingivectomy, gingivoplasty, excision of tumours, excision of biopsies, and second stage recovery of implants.<sup>1</sup>

### Mechanism of Action

The laser consists of an energy source, an active lasing medium, and two or more mirrors. In the dental laser, the light reaches the target tissue via the fiberoptic cable, hollow wave guide, focusing lenses, and cooling system.<sup>4</sup>

The Amdt-Schutz principle is the basis for the action. This means that the increase or decrease of the stimulus beyond the optimal dose will lead to weakening or absence of the effect. The optimal effect is created with the optimal dose. Accordingly, the bio stimulation effect of LLLT can be produced by optimal dose exposure to tissues in a non-contact mode. In addition, LLLT deposits sub-thermal energy within tissues, which acts on the sub-cellular component. The application of LLLT also stimulates various cells lymphocytes and mast cell which will produce anti-inflammatory actions causing changes in the capillary hydrostatic pressure which results in oedema absorption and elimination of intermediary metabolites. Even it can increase collagen production, the mitotic activity of epithelial cells and fibroblast. Moreover, it can produce an analgesic effect by inhibiting nociceptive signals.<sup>1</sup>

There are two types of beams used in dentistry, which are the visible beam like the argon laser and the invisible beam in the infrared range like the carbon dioxide laser, erbium substituted yttrium aluminium garnet, erbium chromium doped yttrium, scandium gallium garnet holmium, yttrium aluminium garnet, and gallium arsenide. There are many properties of the laser beam, especially the wavelength and optical features of the specific target tissue, which show the type and the extent of the interaction that might occur.<sup>8</sup>

The lasers used for surgical purposes emit light at specific wavelengths which have direct effects on the tissue not only on the coagulation and vaporization but also on the natural healing process of the cells. There are other kinds of lasers other than surgical lasers that are used as bio stimulators.<sup>1</sup>

There are different wavelengths which can be classified into:

- the UV range (ultra-spectrum 400-700 nm)
- the IR range (infrared spectrum 700 nm to microwaves spectrum)
- the VIS range (visible spectrum 400-700 nm)

The laser converts the electromagnetic energy to thermal energy and the wavelength depends on both design and clinical application.<sup>2</sup>

### Dose Calculation

To calculate the dose, the given energy will be used as mWx seconds (eg. 100 mW x 10 seconds = 1000 mJ = 1 J). The dose is calculated by dividing the energy by irradiation area. An optimum power density is important to trigger biological effects so that the low output will not be fully compensated by long exposure; and the depth of treatment target site is in consideration. Even while using the laser probe, the target tissues and the type of tissues must be taken into consideration. For example, transmission of the laser light is easier through fat and mucosa than through muscle. In addition, the haemoglobin and pigments are strong absorbers; therefore, there is a need to increase the dosage. The penetration can be advanced by using pressure moving the laser closer to the target.<sup>9</sup>

In case of acute conditions, which contain inflammation and oedema, high doses of laser energy are applied and it may require a more frequent application for resolving. In cases of chronic conditions such as paraesthesia and pain, patients are treated conservatively, with the laser application being on a weekly or twice a week basis. The effects of LLLT given on the first day will linger on the second day as well as adding a long-term build-up of inhibitory levels. In chronic conditions, a flare-up is experienced in a well-responding patient as the condition is transformed into an acute phase, which allows the healing process to begin. The number of sessions indicated for LLLT varies. In certain cases, a single visit of the therapy may suffice but in most conditions, multiple sessions are required.<sup>1</sup>

### Effects of Lasers

The initial clinical experimental uses of lasers in dentistry were in 1964. The otolaryngologists, periodontists, and oral surgeons were the first specialists who used medical lasers intraorally to perform surgical applications in the soft tissue. Laser surgery in the sites, which have a lot of bleeding like cheeks, the floor of mouth and tongue provides good access to and control for the surgery.<sup>3</sup>

There are many dental indications of LLLT. Anaesthesia has shown a positive effect on reducing the trauma to vessels or nerves that may be caused by the puncture of the needle in some cases. LLLT can be applied directly to the superficial mucosa before the injection, which will produce a good aesthetic effect, but it cannot be applied to the hard palate. Oedema, which is due to an increased inflammatory process depends on the lymphatic system. If LLLT is applied directly to the lymph nodes, it will reduce oedema. Widespread oedema will need high doses and multiple visits to get relieved. Pain is limited with therapeutic lasers as they reduce the velocity of nerve conduction and action potentials as well as the suppression of noxious stimulations. Initially, in acute pain, there will be a decrease in the level of PGE2 and other inflammatory markers by direct inhibition of peripheral afferent terminals which suppress peripheral sensitization and limit the releases of neurokinins. The high doses of lasers will reduce the inflammatory cells and processes, thereby reducing the pain sensations. In chronic conditions, it differs as it depends on the sensitization more than inflammation. Dental lasers are beneficial as there is an interaction of the specified area of the diseased tissue and a great reduction in the number of bacteria and pathogens with the use of lasers in the surgical field. In case of the soft tissue procedures, they achieve sufficient healing which may sometimes eliminate the use of sutures. Many researchers have seen that the effects of a laser can reduce the effects of edema because it seals the blood vessels and lymphatic channels properly.<sup>1</sup>

The light energy that is produced from the laser machine has interaction with the diseased tissue. First, by the reflection of the beam that is redirected off the surface which has no effects on the targeted tissue and if the light maintains its collimation through the narrow beam, it might become more diffuse. But this reflection may cause harm as it could be reflected onto the non-targeted tissues like the eyes; for e.g. when the CO<sub>2</sub> lasers are using in the exposure of titanium implants, they cause a more diffuse reflection. By the transmission directly through the tissue, there is no effect on the targeted tissue, depending on the wavelength of laser lights. Scattering of the light makes the intended energy weak. This is important in the infrared lasers for healthy soft tissue, and this will cause the photons to change their directions. Absorption of the laser energy is the usual desirable effect and the amount of absorption will depend on the pigmentation and water

content.<sup>1</sup>

Therapeutic laser light is a kind of light that stimulates the biological process and affects mostly the cells in an oxidation reduction reaction. The cell will be acidic in this stage but after the laser is done, the cell will become more alkaline and less acidic and will be able to perform its normal functions. The most important thing is to increase the adenosine triphosphate and it is mainly produced at the end of the Krebs cycle where the photon acceptor enzyme cytochrome is inhibited by nitric oxide. The laser light will initiate the binding between the nitric oxide and cytochrome-c oxidase, which will allow it to resume the action and production of the adenosine triphosphate enzyme. The principle is to supply the direct bio-stimulative energy to the body cells, and cellular photoreceptors will also absorb the low-level laser light which will produce ATP. The photochemical theory is the most accepted theory that is shown to explain the effects and the mechanisms of lasers, by which the light is absorbed by specific molecules and then some biological events will happen. Photoreceptors are some kinds of endogenous proteins and molecules in the respiratory chain such as cytochrome c-oxidase that will lead to increased ATP. This type of laser has been used for about 30 years and there are still no certain reports of harms caused by it.<sup>10</sup>

Electromagnetic energy is available in waves from the tiny gamma rays, with wavelengths of about 10-12 m and thousand meters of the wavelengths to the radio wave. The current available dental laser instruments have emission wavelengths for about 488 nm to 10600 nm and all of them are in the non-ionizing radiation category. This is to be differentiated from the ionizing radiation whose effect on DNA has been shown to be mutagenic. The dental lasers produce thermal, heat and radiation. Some dental lasers emit light that is visible. For instance, argon lasers emit blue light of 488 nm and as the frequency is doubled, they emit blue and green light of 514 nm. Of the two main instruments that emit visible light, the Nd:YAG emits mainly the green light at a wavelength of 532 nm, and the low level lasers emit light at a wavelength of 635 nm for photobiomodulation and at a wavelength of 655 nm low level lasers can be used for caries detection. Other laser devices that are used for soft and hard tissue surgery produce the laser on the middle, near infrared part of the electromagnetic spectrum, with one exception which is the low-level laser in the range of 810nm. Surgical diode lasers ranging between 800-830 nm diode use an active medium which consists of aluminium, gallium and arsenate; this media is also used in a 980 nm diode laser as well as that of a 1064 nm diode laser. Nd-YAG lasers include YAG which is the crystals of yttrium scandium, gallium and garnet doped with erbium and chromium; however, Er:YAG at a wavelength of 2940 nm uses erbium as the doping agent and a wavelength of 10600 nm utilises carbon dioxide.<sup>11</sup>



### Laser in Oral Mucosal Lesions

Lichen planus is a type of disease which has an unknown cause. The T-lymphocytes are the ones that are responsible for the pathogenesis. It has two forms of keratotic, which are the white lesions having no symptoms and no treatment is needed and non-keratotic which is the red lesion requiring treatment to relieve the symptoms and to reduce the malignant action of it and there are many ways in treating this lesion like corticosteroids, photo-chemotherapy, lasers, and surgery. LLLT was introduced especially for treating the erosive lichen planus type with very minimal side effects. In addition, there are two types of effects that a low-level laser produces: primary and secondary. Primarily, it causes vasodilation, lymphatic drainage, cellular activity and metabolism, enhancement of the flow of blood, activation of fibroblast and neutrophils, and stimulation of pain threshold. The secondary effect is the aggregation of prostaglandin, immunoglobulin and lymphocytes, and beta-endorphin in the tissue encephalin. Therefore, this will reduce infection and inflammation, pain, soreness, and immune response.<sup>12</sup>

Many kinds of LLLT, which are used to treat oral lichen planus, include ultraviolet (waves of below 350 nm length), Helium neon (632 nm), and diode (red infrared wavelengths 600 to 1100 nm) lasers and these premalignant lesions like oral lichen planus can interfere with daily activities like eating and speaking. Corticosteroids is the first treatment one can go for in these cases, but we should be careful because it has many side effects. Diphenhydramine or local anaesthetics might be used in conjunction with corticosteroids and antifungal to treat cases of candidiasis, but it may reduce the patients' compliance. Some studies showed lesions and pain remission by using a 630 nm laser for 10 sessions a month with the power of 1.5 J/cm<sup>2</sup>.<sup>12</sup> Trehan et al used a 308 nm excimer laser in eight non-responsive painful oral lichen planus and the sessions were every week for 7 months and 1-400 power was emitted.<sup>13</sup> In a study by Köllner et al, 75 to 150 mJ/cm<sup>2</sup> powers of a 308 nm excimer laser were emitted to oral lichen planus lesions 3 times per week for 32 sessions. One patient showed remission after 12 sessions with no signs of relapse one month later. Four patients were relative and 2 were absolute non-responders. Pain was gone after 10 sessions in this report.<sup>14</sup> A 308-nm excimer laser emits ultraviolet B (UV-B) rays with a tissue penetration of less than 0.3 mm, whereas a 630 nm red light laser penetrates deep into tissue with a reduction in the inflammatory response, pain, and ulcer healing effects. The UV-B excimer laser is potentially a carcinogen; erythema, erosion and soreness are other side effects of its use, but no side effects were reported on the application of the red laser.<sup>13,14</sup> Erosive lichen planus is mainly treated by a 630 nm low-level laser which decreases the pain and soreness without side effects.<sup>15</sup> The therapy of lichen planus by a diode laser has

shown that it can reduce the reliving signs and symptoms of oral lichen planus. LLLT also showed very good results as an alternative treatment. Er-YAG lasers were effective in minimizing lymphoplasmacytic infiltrate. Clinical case reports have shown that CO lasers are very good at treating histopathologically diagnosed lichen planus as they produce very good results.<sup>14,15</sup>

Oral leukoplakia has also shown regression with laser therapy. CO<sub>2</sub> lasers are very beneficial in treating oral leukoplakia. It causes minimal swelling and pain. Photodynamic therapy with 5-aminolevulinic acid and a pulse dye laser is used to maintain the regression of the leukoplakia. Although it is less invasive and painful and it shows better aesthetics, there has been a reoccurrence of the dysplastic oral leukoplakia after oral surgery in the instances of smoking directly after the surgery. So changes in oral habits have a great influence on the outcome of the laser surgery.<sup>16</sup>

Oral mucositis which is considered as the most painful oral lesion requires narcotic analgesic and can reduce the quality of life. Factors that influence the growth of the oral mucositis are chemotherapeutic regimen, the type of malignancy, patients' age, neutrophil counts and the use of oral care measure. There are many side effects for the oncologic therapy such as ulcerations, alopecia, thrombocytopenia, neutropenia, and oropharyngeal mucositis. The condition is worsened if accompanied by poor oral hygiene, pre-existing intraoral lesions, deficient immune status, and high-level pro-inflammatory cytokines. The most involved tissues are the non-keratinized tissues, the lateral borders of the tongue, and the floor of the mouth, and many therapeutic and preventive measures such as analgesics, cryotherapy, antibiotics, anti-inflammatory agents' growth factors and biological mucosal protectants should be considered. The application of LLLT has shown a significant reduction in the pain associated with oral mucositis as well as quicker healing of the oral lesions.<sup>17,18</sup>

Fordyce granule excision using a combination of the low-intensity and high-intensity lasers has produced increased aesthetics results and quicker healing with reduced postoperative pain and inflammation.<sup>19</sup>

### Conclusion

The application of laser treatment in maxillofacial medicine has potential implications for quicker treatment and faster healing. The soft tissue laser is a state of the art tool that creates predictable aesthetics results within general dental practice. Lasers have significantly contributed to dental clinical practice in the 21st century and they will play a very important role in the dental practice in the coming future.

### Ethical Considerations

Not applicable.

**Conflict of Interests**

The authors declare no conflict of interest.

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