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Lasers and Its Applications in Dentistry: A Brief Review

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Abstract:

The word Laser stands for "Light Amplification by the Stimulated Emission of Radiation". It was introduced in dentistry in 1960s, but gained popularity in dentistry in 1990s. Many branches in dentistry use the present laser technology for various hard and soft tissue applications. The lasers are considered the minimally invasive procedures with much less discomfort to the patients and increased efficiency. Lasers and its advancements in the field of dentistry have revealed a paradigm shift in dentistry with promising results in various dental procedures. This article describes in brief the uses of lasers in dentistry and its various applications in different dental specialties.

Keywords: *Lasers, Laser Dentistry, Argon Laser, CO2 Laser, Diode Laser, Dental application*

Introduction

The term laser is an acronym of light amplification by stimulated emission of radiation [1. Lasers are intense beams produced by stimulated emission of radiation from a light source [2]. Introduction of laser in dentistry, in the 1960s, by Miaman,[3] has led to a continuous research in the various applications of lasers in dental practice. In dentistry lasers are applied in mainly two ways, one on both hard and soft tissues such as, Carbon dioxide (CO2), Neodymium Yttrium Aluminum Garnet (Nd: YAG), and Er:YAG, whereas, other on soft lasers, based on the semiconductor diode devices, which are compact, low-cost devices used predominantly for applications, are broadly termed as low-level laser therapy (LLLT) or ‘biostimulation’. [4] On account of the ease, efficiency, specificity, comfort, and cost over the conventional modalities, lasers are indicated for a wide variety of procedures in dental practice. The aim of this review is to primarily focus on the various applications of lasers, in dentistry.

History

The term LASER was first introduced to the public in 1959, in an article by a Columbia University graduate student, Gordon Gould. [5] 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 photo-stimulation of herpetic lesion. It has been discovered that lasers have increased the efficiency, specificity, ease, cost, and comfort of dental treatment. [6]

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 1964,5 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. [5] 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.

Classification

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. 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. [6] (Table 1)

Type of Lasers	Wavelength (nm)	Tissue being Targeted
Diode	850-1064	Gingiva, Mucosa
Nd: YAG	1064	Gingiva, Mucosa
Er: YAG	2940	Gingiva, Mucosa, Enamel, Dentine , Bone
Er, Cr: YSCG	2860	Gingiva, Mucosa, Enamel, Dentine , Bone
CO_2	10640	Gingiva, Mucosa, Enamel, Dentine , Bone

Table 1 - Wavelength of laser light used and target tissue

Nd:YAG: Neodymium-Doped:yttrium Aluminum Garnet,

Er:YAG: Erbium:Yttrium Aluminum Garnet,

Cr:YSGG: Chromium:yttrium-Scandium-Gallium-Garnet

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.

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.

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.

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. 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.

Mechanism of Action

In the dental laser, the light reaches the target tissue via the fiberoptic cable, hollow wave guide, focusing lenses, and cooling system6. 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.

Laser light is a monochromatic light and consists of a single wavelength of light. It consists of three principal parts: An energy source, an active lasing medium, and two or more mirrors that form an optical cavity or resonator. For amplification to occur, energy is supplied to the laser system by a pumping mechanism, such as, a flash-lamp strobe device, an electrical current, or an electrical coil. This energy is pumped into an active medium contained within an optical resonator, producing a spontaneous emission of photons. Subsequently, amplification by stimulated emission takes place as the photons are reflected back and forth through the medium by the highly reflective surfaces of the optical resonator, prior to their exit from the cavity via the output coupler. In dental lasers, the laser light is delivered from the laser to the target tissue via a fiberoptic cable, hollow waveguide, or articulated arm. Focusing lenses, a cooling system, and other controls complete the system.

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.

When a laser is absorbed, it elevates the temperature and produces photochemical effects depending on the water content of the tissues. When a temperature of 100°C is reached, vaporization of the water within the tissue occurs, a process called ablation. At temperatures below 100°C, but above approximately 60°C, proteins begin to denature, without vaporization of the underlying tissue. Conversely, at temperatures above 200°C, the tissue is dehydrated and then burned, resulting in an undesirable effect called carbonization. Absorption requires an absorber of light, termed chromophores, which have a certain affinity for specific wavelengths of light. The primary chromophores in the intraoral soft tissue are Melanin, Hemoglobin, and Water, and in dental hard tissues, Water and Hydroxyapatite. Different laser wavelengths have different absorption coefficients with respect to these primary tissue components. [7,8]

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.

This property of laser transmission depends on the wavelength of laser light used. There is the transmission of the laser energy directly through the tissue without producing any effect on the target tissue. Nd:YAG, Argon and diode laser light gets transmitted through water, whereas tissue fluids readily absorb the erbium family and CO2 at the outer surface so there is little energy transmitted to adjacent tissues. [9]

The laser reflection is the 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.

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. [9] 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.

Applications In Dentisry

Oral medicine

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. 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. [2,12]

Oral leukoplakia has also shown regression with laser therapy. CO2 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. [11]

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. [12,13]

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. [14]

Endodontics and Restorative dentistry

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. [15-17]

Prevention of Caries

Lasers can be used for removal of incipient caries, sealing pits and fissures. CO2 and Nd:YAG lasers can remove the organic and inorganic debris found in pits and fissures. Terry Myers (1985) used Nd:YAG laser for debridement of incipient caries. The lased fissure areas appeared similar to that of normal enamel. After argon fluoride laser, when topical fluoride treatment was performed for conditioning of enamel, significant reduction in enamel acid demineralization was observed.

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. [18,19] 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.

Etching of Enamel and Dentin

Enamel absorbs the laser thereby causing the enamel surface to be heated to a high temperature, generating micro cracks in the surface which aids in enhancement of adhesion of composite to the tooth structure. The surfaces appear similar to the acid etched surfaces resulting in significant improvement in shear bond strength of resin composites to lased surfaces. [20]

Laser Assisted Bleaching

The primary 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. [21]

Desensitization

Lasers are effective in the treatment of hypersensitivity because of its ability to close dentinal tubules because of its change in hydraulic conductance.

In Root Canal Preparation

Dentin of root canals can be fixed by short exposures of either CO2 or Nd:YAG laser. As a result, the fused dentin crystallize into a glazed, non-porous surface, which used in decreasing dentinal permeability following root canal obturation. After plugging filling materials in the root canal, it can be used into a continuous non-porous surface, as it allows little microleakage. [22]

The laser apicoectomy

Endodontic application of the CO2 laser for periapical surgery was studied by Leo J Miserendino (1988). He found that out it has several advantages like improved haemostasis, potential sterilization of the infected root surface and apex and reduced risk of contamination of the surgical site by elimination of the aerosol producing air turbine handpiece. [35]

In Paediatric Dentistry

Frenectomy and Ankyloglossia

In an attempt for diastema closure, a laser-assisted frenectomy could be done with Er: YAG laser when hyperactive labial frenum is present. It is also used for surgical management of ankyloglossia or severe tongue tie in infants and children. [24]

Exposure of Unerupted Tooth

Er: YAG, Nd:YAG, and Er-Cr: YSGG lasers are used to expose a unerupted or partially erupted tooth for orthodontic bracket or button placement. [24]

Pulpotomy of Primary Teeth

Pulpotomy of primary teeth using didode laser showed 100% success rate after 1 year follow-up and proved to be a better alternative than ferric sulfate and electrosurgery clinically and radiographically. Jeng-fen Liu et al (1999) evaluated the effects of laser pulpotomy in primary teeth and found all the teeth irradiated with laser were clinically successful in a 6 months follow-up visit except one. [24]

Direct and Indirect Pulp Capping of young Permanent Teeth

CO2 laser is used for direct pulp capping as it controls hemorrhage and sterilizes the exposure site which facilitates better placement of calcium hydroxide paste at exposure site and induces favorable clinical outcome. [24]

Periodontics

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.

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. actinomycetemcomitans and P. gingivalis.

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.

Laser Assisted Incisional and Excisional Biopsy

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. Other excisional procedures that can be easily performed using lasers are the removal of benign growths such as fibromas or papillomas.

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 apoptosis.

Oral Surgery

Many different laser wavelengths have been used in Oral and maxillofacial surgery. Since there is excellent absorption of CO2 laser at wavelength of 10,600 nm in the water-based tissues, it is widely indicated in oral surgical procedures performed intraorally and extraorally. CO2 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.

Limitations

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.

Conclusion

The use of laser technology has been widely used in dentistry. The field of laser-based photochemical reactions holds great promise for additional applications, particularly for targeting specific cells, pathogens, or molecules. A further area of future growth is expected to be a combination of diagnostic and therapeutic laser techniques.

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