Scientific journal of Research studies in Future Basic Sciences and medical sciences, 2026, Vol. 4, No. 2, pp. 15-20

Scientific journal of Research studies
in Future Basic Sciences and medical sciences
www.journalhi.com/sci/

The use of laser and their applications in maxillofacial surgery

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Abstract

The increasing spread of new sciences and the presentation of these sciences to other scientific fields is an inevitable phenomenon. The science of optics and laser as one of the new and interdisciplinary sciences in recent decades has played a significant role in the development and facilitation of many processes. Dentistry, as one of the oldest disciplines, also uses laser potentials in various functional dimensions. Oral surgery to reduce the risk and minimize the invasion of the patient is one of the outcomes of laser use. However, the need to optimize the implementation processes of this technique is always considered. Therefore, the present study evaluates the potentials of using laser in maxillofacial surgery and evaluates the conditions and possible applications in this case.

Keywords: laser, maxillofacial surgery, Dentistry

1- 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 published the prototype for the Nd: YAG laser (2). The first application of a laser to dental tissue was reported by Goldman et al and Stern and Sognnaes (3,4). However, modern relationship of operative dentistry and laser takes its origins from an article published in 1985 by Myers and Myers, describing in vivo removal of dental caries using a modified ophthalmic Nd: YAG laser (4,5).

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.

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.

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.

2. Material and Methods

This narrative review synthesized literature retrieved from electronic databases primarily PubMed, Scopus, and Web of Science. Selection prioritized research detailing laser-tissue interactions and surgical outcomes, while strictly omitting non-surgical restorative reports. By analyzing biophysical parameters alongside clinical efficacy, this qualitative synthesis provides an evidence-based overview of laser applications. This methodology connects theoretical physics with practical surgical implementation, ensuring the validity of the reviewed outcomes.

3. Mechanism of Dental Laser Action

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

3.1. 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.

3.2. Amplification

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.

3.3. 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.

3.4. Radiation

refers to the light waves produced by laser as a specific form of electromagnetic energy6,7. 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.

3.5. Tissue interaction

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-thermal8, and any mechanisms may be secondary to this process or may be totally independent. In general, lasers have four different interactions with the tissues.

4. 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 lasers are available based on the wavelengths, which can be used in oral surgery. The most commonly used nowadays are the following (Tab. 1):

4.1. CO2 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 CO2 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. CO2 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.

4.2. Erbium Laser

The erbium "family" laser has two wavelengths:

4.2.1. 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);

4.2.2. (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 CO2 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, CO2 lasers show very high absorption on the tissue surface.

4.3. 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.

4.4. 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.

4.5. 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 lasers are the ease of operation, the sub-millimeter dimension and their extreme compactness (21,22,23).

Generally, surgical procedures in soft tissue require a cautious approach. For instance, an 810nm diode and CO2 lasers are very well suited for frenectomies (operations on the frenula of the lips, cheeks or tongue).

5. Application of Lasers in Oral Surgery

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

5.1. 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 CO2, 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.

5.2. 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, CO2, Ho:YAG etc. have not been proven so effective for use in hard tissue procedures.

6. 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.

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