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Lasers in Dentistry: Basic Concepts and Types – A Review

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Introduction

'Lasers' and their various applications in dentistry have been widely researched since the 1900s. Since lasers have various advantages, they are indicated for a variety of prosthetic procedures. As lasers have become an inevitable tool for modern dental practice, a proper understanding of laser physics, its advantages and safety aspects has become a necessity. This article gives an overview of the science behind laser application in prosthetic dentistry.

History[1,2,3]

In the early 1900s, the theories of quantum mechanics were given by Bohr. In 1958, Shawlaw and Townes discovered laser. The first step towards development of ruby laser was in 1960 by Maiman of Hughes Research Lab. Widespread research was carried out by Stern and Sognnaesin 1965. In1988, Pagdhiwala tested the ability of Er: YAG laser to ablate dental hard tissues In the year 1990, the first pulsed Nd: YAG laser designed specifically for the dental use and in 1997, FDA clearance for the marketing of the first true dental hard tissue Er: YAG laser was obtained. Diode lasers were developed in 1990s.

Advantages[4]

1. Lasers enable procedures with minimal pain and bleeding, that results in clean surgical field, and fine incision with precision is possible.
2. Minimal requirement of anesthesia
3. The risk of infection is reduced as a more sterilized environment is created as the laser kills bacteria.
4. No postoperative discomfort, minimal pain and swelling, generally doesn't require medication.
5. Superior and faster healing, offers better patient compliance.

Disadvantages[4]

1. Lasers cannot be used to remove defective crowns or silver fillings, or to prepare teeth for bridges.
2. Lasers can't be used on teeth with filling already in place.
3. Lasers don't completely eliminate the need for anaesthesia.
4. Lasers treatment is more expensive as the cost of the laser equipment itself is much higher.

Laser Physics

The word laser is an acronym standing for *"Light Amplification by Stimulated Emission of Radiation."* A laser beam is created from a substance known as an active medium, which when stimulated by light or electricity produces photons of a specific wavelength.

The three important characteristics of laser light include :

(1) Monochromatic- Monochromaticity means that a laser beam is made of a single wavelength of light. All dental lasers are found in the visible or infrared portion of the electromagnetic spectrum

(2) Unidirectional - Once a laser beam is produced it will travel in one direction (unidirectional), though the divergence of the beam varies by type of laser and the associated transmission hardware.

(3) Coherent - Coherence is the property that not only is a laser a single wavelength but all the peaks and valleys of each wave travel in unison.

A laser beam is created from a substance known as 'Active Medium' which when stimulated by light or electricity produces photons of a specific wavelength. The active media can be solid state or gas or semiconductor.

- Solid state – Light emitting excitable atoms are introduced into the crystal matrix to alter its electrical properties (doped). Eg.Er:YAG
- Gas – Active medium in gaseous form is sealed in an airtight chamber. Eg. CO_2 laser
- Semiconductor – Active medium is a semiconductor which when stimulated with electricity, emits laser light. Eg. Diode laser

Production of laser beam[5,6]

Stimulated emission is a phenomenon that occurs within the active medium. The step-wise production of laser beam is shown in Table 1, Figure 1,2. The laser beam is carried to the target tissue by the beam transfer hardware. This could be a *Flexible Hollow Waveguide* which is used in non-contact mode, or a *Glass Fiberoptic Cable*, which is used in contact mode.

Thermal and physical implications of pulsed versus continuous emissions

Energy, which is measured in mill joules (mJ) in the laser unit, is controlled by the operator. Power, is the energy used over a period of time, and measured in watts (1 watt = 1J/ sec). The power of a laser beam is the wattage displayed on the laser unit (mJ/pulse x no. of pulses/sec). The thermal implications of the various types of laser beams are described in Figure 3

Tissue interactions[7]

Once a laser beam is produced it is aimed at tissue to perform a specific task. As the energy reaches the biological surface, one of four interactions will occur. (Figure 4)

1. *Absorption* – Chromophores are specific molecules in the tissues that absorb the photons. The light energy is then converted into other forms of energy to perform work.
2. *Reflection* - The laser beam bounces off the surface with no penetrationor interaction at all. This is an undesired effect, eg: Erbium lasers reflect away from titanium surface allowing for safe trimming of gingiva around implant abutments.
3. *Transmission* - The laser beam passes through superficial tissues to interact with deeper areas. eg: During retinal surgery, the laser beam passes through the lens to treat the retina.
4. *Scattering* - Once the laser energy enters the target tissue it will scatter in different directions. This phenomenon is helpful in biostimulative properties of certain wavelengths.

Absorption is the most important interaction. Specific chromophores absorb specific wavelengths. Near infrared lasers, like diodes, and Nd:YAG, are absorbed by pigments like haemoglobin and melanin. Erbium and CO_2 laser wavelengths are absorbed by water and hydroxyapatite.

Biological effects[7,8]

Five types of biological effects can occur once the laser beam enters into the tissue.

1. *Fluorescence* – When actively carious tooth is exposed to 655nm wavelength of Diagnodent diagnostic device, the amount of fluorescence emitted is proportional to the size of the lesion. This is useful in diagnosing early carious lesions.
2. *Photo thermal effect* – The chromophores absorb laser energy and heat is generated. The heat is used for ablating the tissue (incising soft tissue or vapourizing hard tissue during cavity preparation), or for coagulation of blood.
3. *Photodisruptive effect/ Photoacoustic effect* – Short pulsed bursts of laser light of extremely high power interact with the water in the tissues causing rapid thermal expansions or microexplosions. These thermo-mechanical acoustic shock waves disrupt enamel and bony matrices causing pulverization of the hard tissue – tooth or bone.
4. *Photochemical reactions* – Laser photon energy initiates a chemical reaction
5. *Photobiomodulation/ Biostimulation*- Photobiologic interaction of the laser beam with the cellular matrix and mitochondria causes increased collagen synthesis, fibroblast proliferation, increased osteogenesis, and leucocyte phagocytosis. This in turn increases blood circulation, decreases pain and edema and speeds healing.

Thermal Interactions[8]

When laser heats up the oral tissues, reversible changes occur below 50°C and irreversible changes occur above 60°C (Coagulation and Protein denaturation – above 60°C, Vapourization – above 100°C, Carbonization – above 200°C).

Commonly Used Lasers in Dental Practice[9]

1. Erbium Lasers –
   - 2 different types of crystals:
     - **Er:YAG** (yttrium aluminum garnet crystal)- **2940 nm**
     - **Er,Cr:YSGG** (chromium sensitized yttrium scandium gallium garnet crystal)- **2780 nm**
   - Chromophore : Water (mainly) and Hydroxyapatite
   - Excellent thermal relaxation with minimal thermal damage to the tissues
   - Applications :
     - Hard tissue applications (shorter pulses of 50 to 100ms) – Photo-disruptive interactions used for tooth preparation and bone cutting
     - Soft tissue application (longer pulses of 300 to 1000ms) – Photothermal interactions used for gingival contouring, frenectomy, pre-prosthetic procedures
2. Nd: YAG Lasers
   - **1064 nm**
   - Chromophore :Pigments in the tissue – haemoglobin and melanin
   - Photothermal interactions are predominant
   - Applications

     – Multiple soft tissue applications like gingivectomy, frenectomy, impression troughing
     - Stimulates fibrin formation – prevents alveolitis and enhances osteogenesis
     - Bacterial decontamination causes resolution of infection

     - Laser beam penetrates deeply into the tissues and has biostimulative properties, used for photobiomodulation procedures
3. Diode Lasers –
   - **Range from 805 to 1064 nm**
   - Most commonly used lasers in clinical dental practice

- Chromophore : Pigments in the tissue – haemoglobin and melanin
- Photothermal interactions are predominant
- Applications –
  - Soft tissue applications only (gingivectomy, frenectomy, impression troughing)
  - Diode lasers have biostimulative and bactericidal properties
  - Laser beam penetrates deeply into the tissues and has biostimulative properties, used for photobiomodulation procedures

4. Co2 Lasers

- **10600 nm**
- Chromophore : highly absorbed by water
- Applications :
  - Traditional CO2 lasers used in super-pulsed modes had soft tissue applications only
    - Used for incising soft tissues with minimal charring
    - Controlled thermal effects and sealing of nerve endings, thus minimal post-operative discomfort
  - Recently developed hard tissue capable CO2 laser of wavelength 9300nm has high absorption affinity for hydroxyapatite, and allows preparation of tooth structure.

Laser Safety[10,11]

Even relatively small amounts of laser light can produce potential damage to the retina of the eye, or even the skin. Thus the safe design, use and implementation of lasers to minimize the risk of laser accidents are essential. A laser safety officer needs to be appointed by the clinic.Commonly recommended safety procedures include :

1. **Eye Protection**– The patient, dentist and dental assistant, and any observers must wear protective eyewear specific for the wavelength being used.
2. **Plume Control-** Plume may contain hazardous chemicals and microflora. Standard dental high-speed evacuation and good quality masks should be used.
3. **Sharps**– Scored laser tips of quartz fibers are considered sharps and need to be disposed of as such.
4. **Warning Sign**– Warning signs need to be in a visible place and access to the operatory limited.

Table 1: Production of laser beam in a solid state Er:YAG laser

Erbium stimulated by light from a flashlamp by a process called optical pumping

⇩

Erbium atoms absorb the photon – electrons elevated to a higher energy

⇩

When the unstable electrons return to a more stable lower energy state – two identical photons emitted

⇩

Resultant photons further stimulate more atoms in a chain reaction. This causes amplification of light

⇩

Microns surrounding the active medium cause reflection and further increase in light energy

⇩

Light leaks from the output coupler – that is less than 100% reflective

⇩

Laser beam is collimated and exits from the handpiece as a beam of light

Conclusion

Dental lasers have proved to be a boon if used effectively and safely. The ability to perform dental procedures with minimal intra-operative and post-operative discomfort, and good healing makes lasers something that every dental practitioner should consider in daily practice. The clinician needs to understand the character of the wavelength of the type of laser being used, the thermal implications and tissue interactions, in order to efficiently use dental lasers for various soft tissue and hard tissue procedures.

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