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FUNDAMENTALS AND PRACTICAL APPLICATIONS OF LASERS IN DENTISTRY - AN OVERVIEW

Dental Science

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ABSTRACT

The oral cavity is a complex environment where hard and soft tissues exists in close proximity and all with bacteria laden saliva. Both hard and soft tissue are vulnerable to laser treatment but the biophysics governing laser tissue interaction demands a knowledge of all factors involved in laser delivery. The aim of this review is to describe the application of lasers in oral soft tissue procedures. Soft tissue lasers are becoming popular among the clinicians due to their potential value in surgical procedures providing surface sterilization, dry surgical field and increased patient acceptance. The aim of this review is to describe the soft tissue applications of lasers in dentistry.

KEYWORDS

Lasers, Soft tissue Applications, Photo stimulation

Introduction:

Laser, an acronym for light amplification by stimulated emission of radiation, is a device for generating a high intensity, parallel beam of monochromatic electromagnetic radiation. This innovative technology works on the principle of stimulated emission theory which was proposed by Einstein in 1917 based on the concept of spontaneous emission theory which was postulated by Neil Bohr in early 1900s. Based on these concepts Maiman developed the first laser prototype in 1960 using ruby crystals as an active medium. The first experiment with lasers in dentistry was reported in a study about the effects of a pulsed ruby laser on human caries. Several laser systems, such as the diode, ruby, Ho: YAG, Er: YAG, Nd: YAG, and yellow light lasers, as well as dye lasers for photodynamic therapy, have been used for treating various diseases. With the recent advances and developments of wide range of laser wavelengths and different delivery systems, lasers could be applied for the dental treatments including periodontal, restorative and surgical treatments. [1]

Soft Tissue Applications of Dental Lasers[2,3]

- Gingivoplasty and Gingivectomy
- Frenectomy / frenotomy
- Implant uncovering
- Gingival troughing / retraction
- Exposing subgingival caries
- Fibroma removal
- Sulcular debridement
- Biopsies incisional and excisional
- Aphthous ulcer treatment
- Soft tissue crown lengthening
- Flap surgery
- Vestibuloplasty
- Haemostasis assistance / control
- Incising and draining abscesses
- Operculectomy
- Soft Tissue Procedures Including Pulpal Tissues
- Root canal debridement and cleaning
- Removal of pathological tissues (i.e., cysts, neoplasm or abscess) and hyperplastic tissues (i.e., granulation tissue) from around the apex
- Treatment of canker sores, herpetic and aphthous ulcers of the oral Mucosa

Considerations when Selecting a Laser[4,5]

- Wavelength
- Peak power
- Emission / duty cycle
- Pulse modes
- Portability
- Ergonomics
- Device cost
- Infection control protocols

For any laser given, Law Tissue Interaction means following factors collectively affect the absorption of Laser light[6]

- Laser wavelength & Emission mode
- Tissue (composition & thickness)
- Surface wetness due to water or saliva
- Incident angle of the laser beam
- Exposure time

Contact/non-contact modes between laser delivery tip and tissue

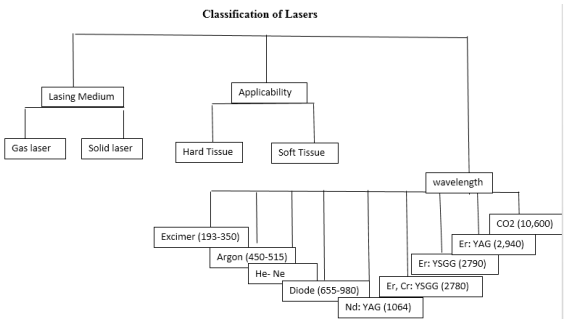

Fig 1: Classification of Lasers

Mechanism of Laser Interaction with Soft Tissue:[7]

Depending on the wavelength of the laser device, the following interactions can be seen in varying degrees:

Reflection – no interaction occurs as the beam reflects off the surface

Transmission – no interaction occurs as the beam passes directly through the tissue

Scattering – an interaction as the beam disperses in a nonuniform manner throughout the tissue

Absorption – light radiation is absorbed by specific tissue elements. The predominant laser interactions within oral soft tissue are absorption and scattering.

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 60 C reached, protein denaturation followed by vaporization of the water occurs at 100 c called ablation. Above 200 c, the tissue become dehydrated then burned resulting in carbonization of tissue occurs.

The ability of laser light energy to ablate (vaporize or cut) tissue is dependent on how well the energy is absorbed by that tissue, the amount of energy or power (watts), and the amount of time the energy is being emitted into the tissue. The key to achieving the maximum efficiency for this tissue interaction is to match these variables with the chromophores (absorbers of light) present in the tissue with a laser that emits the proper wavelength. The chromophores found in oral soft tissue are water, haemoglobin, oxyhaemoglobin, and melanin. With oral soft tissue being comprised of approximately 70% water, it is the primary chromophore that the laser should be targeting.

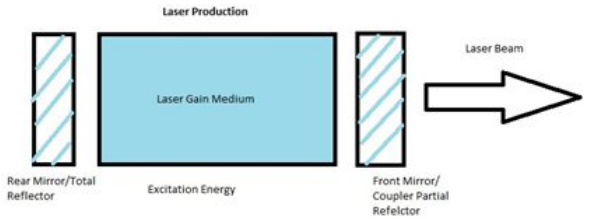

Fig 2: Mechanism of Action

Table 1: List of chromophores Targets

Laser device	Primary target soft tissue chromophore
Diode	Melanin/ Haemoglobin
Nd: YAG	Melanin/ Haemoglobin
Nd: YAP	Melanin/ Haemoglobin
Er, Cr: YSGG	Water
Er: YAG	Water
Co2	Water

EFFECTS OF LASER - SOFT TISSUES CHANGES: [7,8]

Soft tissue ablation is due to photo thermolysis chromophore absorption is by pigmented molecules (haem, melanin) with short wavelength (532- 1064nm) whereas longer wavelength experience greater interaction with tissue water components (H2O and -OH) with peak absorption occurring at approximately 3000nm to 10,600nm. Shorter wavelengths tend to penetrate soft tissues with U shaped cross-sectional appearance of photonic energy through scatter depths of 2-6mm with both back and forward scatter of photons in to the tissue. Soft tissue ablation causes protein denaturation and conductive effects as the tissue is heated which produce zone of ablation surrounded by zone of reversible oedema and little evidence of acute inflammatory response. Longer wavelength needs V - shaped cross-sectional appearance for the purpose of laser tissue interaction occurs at within the confines of tissue surface and as an incision is developed the majority of excess energy is released through the escape of vaporized tissue water.

Controlling the amount of energy in each pulse of the laser light and the amount of time that it interacts with the tissue also has a significant impact on the laser's efficiency. There is a linear relationship between the energy in a pulse of light energy and its ablation efficiency. This increased efficiency causes a decrease in the side effect of collateral thermal damage. Thus, the higher the peak power of a laser, the more efficiently it can ablate the target tissue. However, proper control of this energy is required to achieve the optimal outcome. The goal in some situations may be to obtain haemostasis, and in others it might be to achieve the proper contour or emergence profile of the gingiva.

Often this is accomplished by managing the length of time the tissue is energized with laser energy relative to the amount of time it is allowed to relax (thermal relaxation), enabling the surrounding tissue to cool before the next pulse, therefore minimizing any collateral tissue damage and postoperative discomfort.

With a high powered 980 nm diode laser (greater than 6 watts), this precision can be further enhanced by using water irrigation for convention cooling, allowing the clinician to precisely control his or her clinical options and modes of treatment. This is especially important for procedures such as biopsies and sulcular debridement (sometimes referred to as sulcular decontamination).

Soft tissue laser, such as diode and Nd: YAG lasers were initially used in soft tissue lesions because of its increased success rate. It was because of the fact that these lasers were well-absorbed by chromophores, such as haemoglobin and melanin which are found abundant in the oral mucosa. The introduction of erbium family in 1990 comprising the Er: YAG and Er, Cr: YSGG lasers made the hard tissue laser a boon for dentistry. Erbium, chromium-doped yttrium, scandium, gallium and garnet (Er, Cr: YSGG) was introduced in 1997 for the surgical needs of clinical dentistry in general practice. The erbium belongs to the rare earth which is embedded in a host crystal. Two host crystals consisting of yttrium, aluminium, and garnet ($Y_3A_5O_{12}$) and yttrium, scandium, gallium, and garnet ($Y_3Sc_2Ga_3O_{12}$) are added to the erbium. The interest to use these hard tissue lasers in the treatment of soft tissue lesion was because of the properties of these lasers which are well-absorbed by chromophore water apart from hydroxy appetite crystals. Erbium laser energy is absorbed by collagen, hydroxyapatite, and water components. It allows the laser to cut soft tissue, tooth structure, and bone. In the noncontact mode, the incision is scalpel-like, with very little haemostasis. In contact mode, it performs soft tissue sculpting with adequate haemostasis. The Er, Cr: YSGG is the world's most advanced dental laser, which is ideal all-tissue laser because all dental tissues contain water, for the multidisciplinary dentist who performs a broad spectrum of procedures. It delivers the highest level of clinician control, operating efficiency, flexibility in tip, and accessory selection. For optimal clinical results and patient comfort in hard and soft tissue procedures, the erbium lasers have set a new standard of clinical performance. These are effective in ablation of various potentially malignant disorders, obtaining biopsy, periodontal plastic surgeries, sulcular debridement and providing incisions in surgical conditions.

Table2: Histological alterations seen in laser treated tissues

Histological alterations seen in laser treated tissues (Kende et al. 2011)	
Epithelial Changes	Blisters Clefts Erosions Any intraepithelial or sub epithelial loss of attachment
Connective tissue Changes	Carbonization Desiccation expressed as dense eosinophilic layer
Vascular Changes	Intraluminal clotted erythrocytes Vascular stasis with presence of gathered erythrocytes Thrombosed or collapsed blood/lymphatic vessels
Changes in cytological morphology	Hyperchromic cytoplasm Cell fusion Loss of normal cell adhesion Presence of hyperchromic nuclei

There are several advantages and disadvantages associated with the application of lasers.[9]

Advantages (Naik 2010, Mahajan 2011)

- Dry surgical field and better visualization.
- Tissue surface sterilization and reduction in bacteraemia.
- Decreased pain, swelling, oedema and scarring.
- Increased patient acceptance.

Disadvantages (Coluzzi & Swick)

- They are relatively high in cost.
- Operations of lasers require specialized training.
- No single wavelength will optimally treat all dental disease.
- Harmful to eyes and skin.
- Slower tissue cutting, reduced surgical precision.

SAFETY ASPECTS:[10]

It is beyond the scope of this paper to analyse all aspects of laser safety. However, pertinent to the use of lasers in surgical soft tissue management would be the use of appropriate safety eyewear by all operatory personnel including the patient; wearing of gloves, gowns, and laser masks by the operator and assistant; use of high-volume evacuation to help capture laser plume; avoidance of flammable agents; and recording all details of laser use in the patient's record. Carbonization of tissue elements in very high temperatures cause collateral tissue damage and post-operative pain. Short-pulse laser emission modes on co axial water spray that may enhance tissue thermal relaxation there by avoiding risk of carbonization. Furthermore, any instrument that is used in a manner involving penetrating tissue or around blood products should be heat-sterilized or disposed of in an appropriate sharps container.

CONCLUSION:

Soft tissue laser treatment can reduce the need for outside referrals and additional appointments, thus increasing comfort and convenience for patients and still providing state–of–the–art clinical care with minimally invasive procedures. There are increasingly significant differences being introduced in dental lasers and it is important to understand the value of these enhancements. It is imperative that each practitioner become properly trained specifically on the lasers they are using to offer the best patient care possible.

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