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Lasers in Orthodontics

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Abstract **Review Article**

Laser technique now is widely applied in orthodontic treatment and proved to have many benefits. Soft tissue lasers can be used to perform gingivectomy, frenectomy and surgical exposure of tooth with less bleeding and swelling, improved precision, reduced painand less wound contraction. Other laser applications include enamel etching and bonding andbracket debonding. Lower level lasers have the potential effects of pain control and accelerating tooth movement. Clinicians must be aware of the safety issues and risks associated with laser and receive proper training before the laser treatment is started.
Keywords: Laser; Orthodontics; gingivectomy; frenectomy; low-level laser; etching bonding.

INTRODUCTION

Laser, is a device that stimulates atoms or molecules to emit light at particular wavelengths and amplifies that light, typically producing a very narrow beam of radiation. The emission generally covers an extremely limited range of visible, infrared, or ultraviolet wavelengths. Laser is an acronym for “Light Amplification by the Stimulated Emission of Radiation.” Lasers were developed in the early 1960's and rapidly found a number of uses in medicine and surgery. Laser energy is produced when a suitable medium is subjected to certain physical constraints at high energy. The medium is stimulated by an external power source to produce photons of light energy which are then amplified to produce laser emission. The mediums are molecules in solid, liquid, or gas state [1].

Basic laser science

According to the quantum theory of physics first described by Niels Bohr [2], a photon which is the smallest unit of energy, is released after an atom has absorbed another photon and is excited. This phenomenon is called spontaneous emission. Einstein [3] further developed this theory. He added that an excited atom may absorb a quantum of energy and then release two photons. Two identical photons travel as a coherent wave. More atoms will be excited by these photons which cause further emission of additional identical photons resulting in an amplification of light energy. Eventually, a laser beam will be produced [4].

Properties of Laser

Three unique properties of laser distinguish it from ordinary light. Monochromaticity: The wavelength of light emitted by laser is very narrow compared to conventional light sources which emit light of a broad wavelength. Therefore, instead of containing multiple colours, laser light has a single specific colour.

Collimation: The beam of a laser has a constant direction, size and shape while conventional lights diverge in all directions.

Coherency: All the light waves are identical in laser light [5].

Basic Components of Laser

A laser device basically contains three major parts: an optical resonant which consists of more than two mirrors, an active medium (gas, dye, solid-state electronic device or semiconductor) and an external energy source (pump source). The external energy sources usually involve a flash-lamp or electricity to excite the active particles in the active medium in order to produce stimulated emission. Photons are then released from the active medium and amplified by mirrors in the optical resonant and eventually emerge as laser light [5].

Laser Delivery System and Emission Mode

A laser beam must be delivered to the target tissue in a precise and ergonomic manner. There are two main delivery systems available for dental laser.

A hollow tube-like wave guide with interior mirror: The laser beam is reflected by the mirrors along the wave guide and exits through a handpiece. The beam works on the tissue in a noncontact fashion (not direct physical contact with the tissue). CO2 laser is delivered with this system.

Glass fiber-optic cable: Glass fiber cable with different diameters (200u to 1000u) can be used to deliver a laser beam. It is encased in a sheath, very fragile and cannot be bent into a sharp angle. This system can be used in both contact (touch the tissue directly) and non-contact fashion, but it is mostly used in contact fashion in oral surgery. Nd: YAG, diode and erbium lasers are delivered with this system.

A laser device emits light energy by three modes. In continuous wave, the laser beam is emitted at a constant power level (argon, diode and CO2). Another mode involves the periodic alteration of the laser energy being on and off in a short amount of time (diode, CO2), this is called gate-pulsed mode. The last mode is named free-running pulsed mode, where a large quantity of energy is released for a short period of time followed by a relatively longer time during which the laser is off (Nd: YAG, erbium and Ho:YAG) [5].

Types of Dental Lasers

Lasers applied in dentistry are named after the chemical elements, molecules or compounds that compose the active medium which is stimulated. There are six basic types of lasers used in dentistry.

CO2 Laser

The CO2 laser is a gas-active medium laser [6, 7]. Wavelength used is10600nm. This wavelength is well absorbed by water and highest absorption is in hydroxyapatite. The laser energy is focused onto the surgical site in a noncontact fashion. CO_2 laser is used in soft tissue surgery and enamel surface modification.

Nd: YAG Laser [8]

Nd: YAG has a solid active medium, which is a garnet crystal combined with rare earth elements Yttrium and Aluminium, doped with neodymium ions. The available dental models have an emission wavelength of 1064 nm. The laser energy is highly absorbed by melanin but is less absorbed by hemoglobin than the Argon laser and is approximately 90% transmitted through water. Nd: YAG laser is absorbed by water and pigment tissue(hemoglobin). Slightly absorbed by dental hard tissue. Common clinical applications are for soft tissue surgery; sulcular debridement and removing surface carious lesion. When used in a noncontact fashion,used for procedures such as hemostasis, treatment of aphthous ulcers, or pulpal analgesia.

Diode Laser [6, 9]

Diode is a solid active medium laser, manufactured from semiconductor crystals using some combination of Aluminium or Indium, Gallium, and Arsenic. The available wavelengths for dental use range from about 800 nm for the active medium containing Aluminium to 980 nm for the active medium composed of Indium.Diode Laser is well absorbed by pigment tissue and water but poorly absorbed by dental hard tissue. The Diode used in contact mode is an excellent soft tissue surgical laser and is indicated for cutting and coagulating gingiva and mucosa and for sulcular debridement. The chief advantage of the diode lasers is one of a smaller size, portable instrument.

Argon Laser

Argon is laser with an active medium of Argon gas that is energized by a high-current electrical discharge. There are two emission wavelengths used in dentistry: 488 nm, which is blue in color, and 514 nm, which is blue green. The 488-nm emission is the wavelength needed to activate camphor quinone, the most commonly used photo initiator that causes polymerization of the resin in composite restorative materials. The 514-nm wavelength has its peak absorption in tissues containing hemoglobin, hemosiderin, and melanin; thus, it has excellent hemostatic capabilities.Poorly absorbed by dental hard tissue. argon laser is used in Light curing dental materials; Sulcular debridement and highly vascularized lesions Caries detection

Er,Cr:YSGG and Er:YAG Laser [4,10]

Er, Cr: YSGG; Erbium, Chromium: YSGG (2790 nm) has an active medium of a solid crystal of Yttrium Scandium Gallium garnet that is doped with Erbium and Chromium. Erbium:YAG (2940 nm) has an active medium of a solid crystal of Yttrium Aluminium garnet that is doped with Erbium. Both of these wavelengths are placed at the beginning of the mid infrared, invisible, and nonionizing portion of the spectrum.Charecterized by highest absorption in water and high affinity for hydroxyapatite.It is used in caries removal, tooth preparation and soft tissue surgery

Ho: YAG Laser [4]

It contains a solid crystal of Yttrium Aluminium garnet sensitized with Chromium and doped with holmium and thulium ions and is fiber optically delivered in free-running pulsed mode. The wavelength produced by this laser is 2100 nm Solid active, crystal of yttriumaluminum- garnet doped with holmium 2120nm. It is absorbed by water 100 times greater than

Nd: YAG is, and using high peak powers it can ablate hard, calcified tissue; however, as a soft-tissue instrument it does not react with hemoglobin or other tissue pigments. The holmium laser is frequently used in oral surgery for arthroscopic surgery on the temporomandibular joint and has many medical applications.

Laser applications in orthodontics

Diagnostic lasers –

A. Three-dimensional laser scanning

This is a method of three-dimensional image capture which has been described by Arridge et al., [10] and further developed by Moss et al., [9]. A low power, Helium-Neon, type II laser is fanned across the subject's face or body and the reflected beam is captured by a video camera. The information is then analyzed by specially developed software and stored on a computer. The image can then be viewed on a computer screen and rotated in any direction so that all the individual features can be viewed. Three-dimensional (3D) laser scanners are increasingly being used in orthodontics to establish databases for normative populations and cross-sectional growth changes and also to assess clinical outcomes in orthognathic surgical and nonsurgical treatments.

B. Holography

Holographs can be used for three – dimensional record collection and stress analysis in hard tissues subjected to various loading forces. Although holograms have been used for three-dimensional facial image recording, their main application in terms of record collection is as a substitute for orthodontic study casts [11] A special camera is required which will take white laser light reflection holograms from study casts (Holocam System 70 camera, Holofax Limited, Rotherwas, Hereford).

Treatment approaches

Soft Tissue Management

It is used for quickly and effectively addressing soft tissue complications associated to orthodontic treatment through bloodless and atraumatic surgical interventions. The benefits of using HILT for soft tissue oral surgery include better hemostasis, decreased postoperative pain and infection rate, minimal tissue contraction, little or no need for sutures, shorter surgical stages, decreased trauma, edema and scarring, besides the reduced need for local anesthetics. Various soft tissue lasers that were used for intraoralsoft tissue procedures were reported by case reports and uncontrolled clinical studies, among which the diode, CO2 and Nd: YAG, are the most dominant ones. Recently, Er: YAG and Er, Cr: YAG gained more attention in their application in soft tissue surgery [7, 12-15]. Its wavelength ranges between 810 and 1,064 nm and is absorbed by pigmented tissues that contain hemoglobin, melanin, and collagen: with no effect on dental or bone tissues

Gingivectomy, gingivoplasty

Enlarged or irregularly contoured gingival margins tend to change the crown height and shape which in turn change the tooth proportion [16]. Therefore, many clinicians find it difficult to accurately place the bracket on the clinical crown center. Sometimes it may not be possible to bond the brackets. During orthodontic treatment, teeth disproportionality caused by gingival overgrowth makes it hard for clinicians to correctly evaluate and judge the axial inclination of the teeth, leading to an unsatisfactory finishing and compromised esthetic result. Gingivectomy and gingivoplasty are required for the correction of problems brought by gingival enlargement.

Frenectomy

Hypertrophic labial frenum which remains inserted in the free gingival margin or on the palatine papillae causes a midline diastema [17]. This type of low frenum can impede the insertion of temporary anchorage devices which are used for the intrusion of upper incisors in the case of gummy smile. A short lingual frenum may cause ankyloglossis, and lead to problems such as atypical swallow, disproportional lower jaw growth and a lower midline diastema [18, 19]. Frenectomy with lasers of different wavelengths has been reported by previous authors.

Impacted tooth exposure

Laser techniques are especially beneficial when applied to perform surgical exposure of teeth which are either impacted at a mucogingival or bone level. Surgical exposure performed by laser is quick, clean and painless. A dry field without contamination of blood results after laser surgery, making it easier to directly bond a bracket on the exposed tooth [20].

Enamel conditioning and bracket bonding with laser

Laser etching is painless and does not involve either vibration or heat; also, the easy handling of the apparatus makes this treatment highly attractive for routine clinical use [21]. Laser irradiation of the enamel modifies the calcium-phosphate ratio and leads to the formation of more stable and less acid soluble compounds, thus reducing the susceptibility to caries attack [22]. Different types of laser such as CO2, Er: YAG, Nd: YAG, and Er, Cr: YSGG have been used in orthodontics for enamel conditioning to bond brackets.

The mechanism of laser debonding includes: thermal softening, thermal ablation or photoablation. Thermal softening occurs when laser with low power density irradiates the brackets until the resin softens. The brackets will slide off the tooth surface with gravity. Thermal ablation and photoablation vaporize the resin when its temperature is raised quickly by high power dentity lasers. The resulting bracket can be blown off the tooth surface [23, 24].

Pain Control

LLLT is a new technique and is defined as the laser treatment in which the energy output is low enough that the temperature of the applied area will not rise above body temperature [25]. The mechanism of pain relief by LLLT is not yet well established. The analgesic effect is believed to be attributed to its anti-inflammatory and neuronal effect [26]. Low-level lasers [27-30]: GaAlAs, GaAlAs diode (twin laser).

Tooth Movement

LLLT was reported to be able to stimulate fibroblast and chondrocyte proliferation, collagen synthesis, nerve regeneration, wound healing, and bone regeneration [31-36]. It was suggested LLLT can accelerate bone remodeling and cause changes in alveolar bone during induced tooth movement. Changes were found in the number and proliferation of osteoblasts and osteoclasts and collagen deposition in both pressure and tension sites [37, 38]. Based on the previous basic science studies, LLLT has been demonstrated to increase the rate of tooth movement during orthodontic therapy.

Bone Regeneration after Expansion

The separation of mid-palatal suture with an increased bone mass in the center can change the maxillary arch shape dramatically. Usually following expansion a retention period of 3 to 4 months is needed for bone regeneration and remodelling [39]. Low-level lasers can accelerate the opening of the mid-palatal suture and improve bone regeneration during and after rapid maxillary expansion according to several studies [40-43]. It can be helpful in reducing the retention time and preventing relapse.

Dental Laser Hazards

Risk associated with laser use

Optical risk

The cornea mainly consists of water, and absorbs the wavelength of CO2, Erbium and holmium lasers. Thus, these lasers can burn the cornea. They can also affect aqueous, vitreous humor and lens of the eye, resulting in aqueous flare and cataract formation. Lasers such as Nd: YAG, diode and Argon are highly absorbed by pigment, and have greater penetration into tissue. Retinal damage caused by these lasers can lead to blindness. Eye protection is crucial for both the clinical staff and the patient. There is specific eye wear for different wavelengths available in the market. No goggle can provide protection against all wavelengths ranging from 400nm to 10600nm. When choosing eye goggles, be aware of the optical density and wavelengths printed on the goggles. It is important that eye wear is chosen for the correct wavelength of laser [44].

Skin hazard

Skin can be penetrated at wavelengths from 300nm to 3000nm. Laser-induced skin damaged includes excessively dry skin, blistering and burning. Clinical staff and patient should be fully covered during the laser therapy. Whilst UV lasers (<400 nm) are not commercially used in dentistry, there is a combined risk of ablative damage to skin structure and possible ionizing effects that may be pre-cancerous. All other laser wavelengths can cause 'skin burns' due to ablative interaction with target chromophores [44].

Non-beam risks

These risks are associated with possible physical damage arising from moveable components of a laser, electrical shock and mains supplies (pressurized air, water). Fire risks, through the ignition of tubing, someanesthetic gases or chemicals (e.g. alcoholic disinfectants), should be identified and avoided [45-48]. In addition, the products of tissue ablation (plume) represent a considerable hazard that can affect the clinician, auxiliary personnel and the patient. Suitable fi ne mesh face masks specific to surgical laser use, gloves and high-speed suction aspiration must be used to control the spread of all laser tissue ablation products [44].

Laser Plume

The emission of noxious plume by the laser vaporization of tissue can obscure the surgical field and contains toxic chemicals and debris including bacterial spores, cancer cells and viruses (Human Papillomavirus HPV, Human Immunodeficiency Virus HIV and herpes). Inhalation of the plume can cause symptoms such as coughing, nasal congestion, nausea and vomiting. Apart from the regular dental protective equipment, high volume evacuation and masks that can filter up to 0.1μm should be added as extra protection during laser therapy [44].

Fire Hazard

Heat generated by the laser beam may cause a fire if in contact with combustible materials or gas. Some precautions must be taken during laser therapy. Any combustible or explosive materials should not be placed in the nominal hazardous zone. Avoiding using any alcohol-based anesthetics and gauze. Use wet or fire-retardant material only. Gas such as nitrogen dioxide and oxygen can only be used by dentist in a close circuit delivery system with high-speed evacuation system (ANSI Z136.3, 2005). Perform the operation near a water source [44].

CONCLUSION

As orthodontic clinicians have become increasingly focused on aesthetics, treatment quality, and increased productivity, new tools and technologies have become available that allow them to produce superior results in a minimal amount of time. One such tool is the dental laser. Procedures easily performed with a dental laser include gingivectomies to enhance aesthetics, allow more ideal bracket positioning, and facilitate hygiene around orthodontic appliances; removal of tissue to expose unerupted teeth and free embedded appliances; frenectomies; and bio stimulation of aphthous and herpetic lesions. However, an evidence-based approach of using laser in orthodontic treatment must be developed.

Laser therapy has influenced the orthodontic treatment in many aspects. The advantages of laser over conventional instruments were reported, which include improved hemostasis, reduced swelling and pain, faster wound healing and precise incision control. Other functions of laser have potential benefits for orthodontic treatment such as enamel etching; bracket debonding, pain control and accelerating tooth movement. Today, laser begins to attract the attention of more clinicians. More solid evidence must be provided to support the advantages of laser. Also, the potential hazards of laser should be taken into consideration and strict safety procedures must be carried out during the application of laser therapy.

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