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LASERS IN ORTHODONTICS – A REVIEW

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LASERS IN ORTHODONTICS – A REVIEW

ABSTRACT
LASERs have been used in the field of dentistry for more than 40 years. Their wide range of application and reduced pain perception and bloodless procedure makes them readily acceptable for clinical practice. They have multiple advantages such as reduction in treatment duration, increase patient's level of acceptance that helps orthodontists to improve on their treatment efficiency, improve smile esthetics by reducing patient discomfort. Pertaining to orthodontics, LASER application includes pain reduction, alternate to routine etching and bonding techniques, accelerating tooth movement, debonding of brackets, numbering of brackets, increase implant stability a, bracket mesh designing, reduction in rate of demineralization and soft tissue procedures namely, frenectomy, gingivectomy, exposure of impacted teeth, operculectomy, papilla flattening, etc. Like any other technique, LASERs have their own disadvantages. This review article is about the use of LASER in orthodontics, their effects on different tissue, mechanism by which it is formed and various types of commercially available LASERs and their uses clinically.

KEYWORDS : LASER, diode LASER, CO2 LASER, gas LASER, solid-state LASER

1. INTRODUCTION

LASER stands for Light Activation by Stimulated Emission of Radiation. It is a term that explains how light gets amplified by stimulated emission. It is a focussed source of electromagnetic radiation / light energy. The source of LASER mainly involves the laser medium which might be in the form of gas / liquid/ solid state element which is distributed in solid crystal or glass matrix or semiconductor (diode) which determines the wavelength of the output, the pump source (electrical discharges, flash lamp, arc lamps or chemical reactions) which stimulates the lasing medium until light energy is emitted and a resonator(or optical cavity) that amplifies the light energy before the stimulated emission exits the cavity.

2. HISTORICAL REVIEW

In 1957, Gordon Gould, first introduced LASER based on Albert Einstein's theory of propogation of light and concept of stimulated emission in 1946. In1960 , Theodore Maiman first used LASER in Hughes Air Craft Company USA by using lasing medium of Ruby which generated high energy intensity light. In dentistry, Ralph Stern, Reidar and Sognnaes first used ruby LASER to vaporise enamel and dentin in 1964. Following this, Kumar Patel introduced use of CO2 LASER in the same year. In 1969, Leon Goldman, first demonstrated the clinical use of LASER on enamel and dentin. Paghidiwala, in 1985, initially demonstrated the use of Er:YAG (Erbium doped solid state LASER) and later used them for hard tissue in 1997 and soft tissue in the subsequent year.

3. COMPONENTS OF LASER

It includes LASER medium, Pump source, Optical cavity/ Resonator, Delivery system, Cooling system and Control Panel.

1. LASER MEDIUM:

The LASER medium is the source from which light is emitted. This medium can be in the form of gas/dye (in liquid), solid state element (distributed in solid crystal or glass matrix) or semiconductor(diode). Once the LASER medium is stimulated, electrons drop from higher energy (Q1) to lower energy state (Q2) This releases light energy which is amplified before exiting through a collimated tube, thus providing a concentrated source of light – LASER beam (Moritz 2006).

Examples of LASER beam include:

1. CRYSTALS, doped with rare-earth ions (e.g. neodymium, yttrium,erbium) or transition metal ions (titanium or chromium) used as Yttrium Aluminium Garnet (Y3Al5O12)
2. GLASSES, e.g. silicate or phosphate doped with laser-active ions
3. GASES, e.g. mixtures of helium and neon (HeNe), nitrogen, argon, carbon monoxide, carbon dioxide or metal vapors
4. SEMICONDUCTORS, e.g. gallium arsenide (GaAs), indium gallium arsenide(InGaAs) or Gallium Nitride(GaN)
5. LIQUID, in the form of dye solutions as used in dye lasers.

2. PUMP SOURCE

In order to fire a LASER, the medium must reach a nonthermal energy distribution known as population inversion. This is achieved through the pump source which provides the external energy source for the medium to reach population inversion. The pump source may be electrical discharges, flash lamps, arc lamps or chemical reactions. The choice of pump source will depend on the type of lasing medium used.

4. OPTICAL CAVITY / RESONATOR

It amplifies the light energy generated from the medium. It is an arrangement of mirrors that forms a standing wave cavity for light waves. Light thus confined in the cavity reflects multiple times, producing standing waves for certain resonance frequencies. The standing wave patterns are called modes which are of two types: the longitudinal mode differ only in frequency while the transverse modes differ in frequencies and vary in intensity pattern across cross-section of the beam.

The resonator differ according to the variation in focal length of the two mirrors and the distance between them or they consist of two facing plane (flat) or spherical mirrors

5. PROPERTIES OF LASER

1. They are monochromatic (one color, one frequency and one wavelength)
2. The waves travel in a single direction without scattering.
3. The photons generated are of same phase

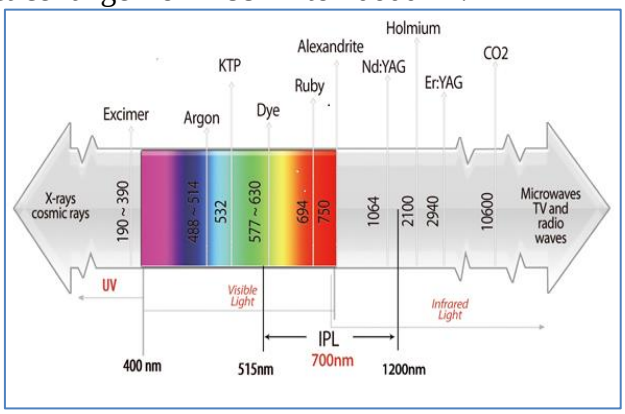
6. CLASSIFICATION OF LASER

They can be categorized according to :

1. EMISSION TYPE: Spontaneous / Stimulated Emission
2. OUTPUT POWER : High/ Medium/Low powered
3. ACTIVE MEDIUM : Liquid/Gas/Solid state
4. TARGET TISSUE : Hard/ Soft tissue
5. BIOLOGICAL DAMAGE: Class I/ Class II/ Class III/ Class IV
6. EXCITATION SOURCE : Continuous (CO2 /diode LASER)/ Pulsating mode (Nd:YAG, Er:YAG,Er,Cr:YSGG)
7. CONTACT MODE (fibre tip is in contact with the tissue – the charred tissue is eliminated with water spray) / NON CONTACT MODE (fibre tip is placed away from the target tissue and it requires visual control with an aid)

7. TYPES OF LASER

LASERs produce light in the visible, infrared and ultraviolet wavelengths. The wavelengths that are most frequently used in dental practice range from 488nm to 10600nm.



BILOGICAL EFFECTS OF LASER ON TISSUE

TISSUE INTERACTIONS:

LASER beam is aimed at tissue to perform specific task. Based on this, once the energy reaches the interface, four types of interactions are possible

1. **ABSORPTION** : Certain molecules, the chromophores absorb the photons. The incipient light energy is converted into other forms of energy.
2. **REFLECTION:** The LASER beam bounces off the surface without interaction or penetration.
3. **TRANSMISSION:** The LASER energy passes through the superficial tissues to interact with deeper area. It is seen with Nd:YAG and diode LASERs.
4. **SCATTERING :** The energy released, once it reaches the tissue, scatters in all directions. They are not desirable and are of no clinical use.

There are 5 different **effects produced by LASER**

1. **PHOTOTHERMAL EFFECT:** When light energy enters a target tissue, it is transformed into heat (Photothermal effect) which results in vaporization of the target tissue cells. This effect occurs when chhromophores absorb the LASER energy and release heat subsequently. This heat is used to perform work such as incising tissue or coagulating blood. Photothermal interaction predominate on soft tissue procedures while photothermal ablation is at work when CO2 LASER are used on teeth as hard tissue is vaporized during removal. Heat is generated during these procedures and thus greater care is required to avoid thermal damage to the tissues.
2. **FLOURESCENCE:** This phenomenon can be during diagnostic procedures when wavelength of approximately 655nm visible wavelength is used on carious lesion. The amount of fluorescence is related to the size of the lesion.

3. **PHOTODISRUPTIVE EFFECT (PHOTOACOUSTIC) :** Short pulsed bursts of LASER light with extremely high power interact with water in the tissue causing thermal expansion of the water molecules. This produces a thermo-mechanical acoustic shock that is capable of disrupting enamel and bony matrices efficiently. This shock wave creates distinct popping sound heard during Erbium LASER use. Thermal damage is very unlikely with no residual heat.
4. **PHOTOCHEMICAL:** The photon generated creates a chemical reaction within the tissue.
5. **PHOTOBIOMODULATION / BIOSTIMULATION**: It refers to the ability of the LASER to increase the speed of healing, increase circulation and reduce pain. Histological changes that occur with biostimulation include increased collagen synthesis, fibroblast proliferation, increase osteogenesis. Most of these reactions are due to interactions of LASER with cellular matrix and mitochondria.
Biostimulation (also known as Low Level LASER therapy) in dentistry is used to reduce postoperative discomfort.

8. CHANGES IN ENAMEL, DENTIN AND PULP

Effects of LASER on tissues include protein denaturation for temperature of 45-60 degrees, coagulation and necrosis (temperature above 60 degrees) and water in tissue vaporizes (for temperature above 100 degrees.
Changes produced in the Enamel, Dentin and Pulp are:
ENAMEL : It results in formation of microcracks mainly due to water vaporing effect.
DENTIN : No cracks are seen but the effect is predominantly in the form of carbonization and necrosis.
PULP : If there is a rise of degrees, it results in irreversible pulpitis but a rise of 1 degrees causes necrosis of pulp.
Deleterious effects on these can be prevented by use of combination of air and water during or immediately after irradiation. This acts as an effective method in the control and reduction of heat transferred to the pulp.

ADVANTAGES OF LASER

LASERs are portable, compact and mostly wireless. They are easier to use, simple to operate and aid in postoperative pain reduction. They also provide a bloodless field.

DISADVANTAGES OF LASER

Relatively higher cost, reduced tactile sensation when compared to conventional scalpel techniques and expertise training required for using them are few disadvantages of LASER.

9. CLINICAL USES OF LASER

1. LASER ETCHING

According to Torun et Al[1] , a meta analysis on laser etching for orthodontic bonding, comparing the effectiveness of Er,Cr:YSGG with 37% orthophosphoric acid on 0.75W/1.5W , concludes that the use of Er,Cr:YSGG which falls into a wavelength of 2780 – 2940nm, for 15 seconds (0.75W/1.5W) produces similar results when compared to the use of conventional orthophosphoric acid. There is formation of micro cracks by alteration of Calcium- Phosphorus ratio (LASER splits the bond of organic and inorganic substances on the tooth surface resulting in explosive evaporation of water that modifies the surface of enamel.

2. LASER BONDING

According to Nadja et al[2] ,AJODO 2007, an in-vivo and in-vitro study on Argon LASER versus conventional visible light- cured orthodontic bracket bonding, concluded that there was no statistically significant difference between the bond strength of AL (10 second) brackets and CCL (40 seconds) brackets and both of them produced the same amount of minimal enamel fracture although argon laser left more adhesive on the tooth surfaces on debonding.

3. EFFECT OF LASER ON INCREASING DEMINERALIZATION RESISTANCE

The use of CO_2 (10600nm), Er,Cr:YSGG (2780 – 2940nm), a review article states that enamel and dentin show micro-cracks that are suitable for resin penetration. Surface etched with LASER is acid –resistant (as it modifies Ca-P ratio) forms a more stable and less acid soluble compound which reduces caries susceptibility. Thus LASER irradiation is a new method for inhibiting demineralization around brackets and other orthodontic appliances which can be combined by fluoride therapy.

4. LASER DEBONDING OF CERAMIC BRACKETS

Ezz Azzeh et Al[4], published a review article that compares LASER with conventional technique of debonding with CO_2, YAG LASERs. It states that the debonding effect is better in monocrystalline than polycrystalline type of ceramic bracket structure. There are three mechanisms by which this occurs :

Thermal softening: The bonding agent is softened and the bracket slides off.

Thermal ablation: There is a quick heating process and the resin temperature raises rapidly to vaporization. This causes the bracket to slip off the tooth surface.

Photoablation: In this method, very high-energy LASER light interacts with the adhesive material such that the energy level of the bonds between the adhesive resin atoms rapidly rises above their dissociation energy levels resulting in decomposition of the material.

5. PAIN RELIEF AFTER SEPARATOR PLACEMENT

Irfan Qamruddin et Al[5], did a single blind study to assess the effect of a single dose of low-level laser therapy on spontaneous and chewing pain caused by elastomeric separators. The type of LASER included in the study was GaAlAs Diode LASER with a wavelength of 940nm at 200mW on continuos mode. On the experimental side, LLLT was given on 3 sites on buccal mucosa for 20 seconds each and on the other side, Placebo LASER therapy was given without turning on the LASER. They concluded that LASER provides adequate pain relief by increasing blood circulation thereby removes pain mediators and enhances cellular activities (BioStimulation).

6. EFFECT OF LOW LEVEL LASER ON ACCELERATING ORTHODONTIC TOOTH MOVEMENT

According to Guram G et Al[6], a randomized control study on the Evaluation of LLLT on orthodontic tooth movement, Journal of Contemporary clinical dentistry, 2018; concluded that There was an increase in tooth movement following LLLT and this can be attributed to increase in revascularization, bone remodelling and collagen synthesis. There is an increased release of interleukin 1 beta and the action was better observed in maxilla than in the mandible. The LASER used was GaAlAs and HeNe with a wavelength range of 600 – 1000 nm. The LASER was applied on buccal and palatal aspect for 80s/2days. The tip was placed on cervical third of the root on buccal and lingual side for 5 seconds. The canine retraction was evaluated on the onset of retraction, 2 months after retraction, 3 months after retraction and upon completion of retraction.

7. SOFT TISSUE LASER

According to Seifi M et Al[7], a study on Laser surgery of soft tissue in orthodontics: review of clinical trials, Journal of lasers in medical sciences 2017, states that soft tissue ablation due to its high absorption in soft tissue than bone results in controlled removal of soft tissue around impacted teeth, unerupted teeth and can be used for crown lengthening for gummy smile correction and gingival zenith positioning. The LASER used was Diode (810 – 980nm) and Er:YAG (2780- 2940nm)

8. 3D LASER SCANNING

According to Kuroda et al[8], AJODO 1996, A study on reliability of 3D laser surface scanning for orthodontic applications, states that surface laser scanner recreates 3D objects on the computer by

triangulating the distances between the reflecting laser beam and the scanned surface, the surface laser scanner and thereby detects object's length, width and depth.

9. LASER MICROWELDING

According to Leigh[9], a study on simulated intraoral LASER welding of Orthodontic Appliances, suggests that rapid and repeatable actions of the pulsed neodymium LASER microwelder can be used a safe intraoral welding unit with no damage to the hard tissues. This has an advantage that it minimizes the time consuming procedures. Thus intraoral welders can be used for construction and placement of retention devices, intraoral welding of space maintainers, periodontal splints, ortho-surgical splints, and attachment of archwire, brackets to existing bands and auxillaries.

10. BRACKET MESH DESIGNING

Titanium brackets with retentive base pads are made with computer aided laser cutting which generated micro and macro undercuts. For Dentaurum brackets, the smooth surface of injection molded single piece bracket base is treated by a sufficiently powerful Nd:YAG LASER, which melts and evaporates the metal and thus produces hole shaped retentions.

10. CONCLUSION

LASERs can thus be used to perform various treatment modalities in a simpler way. Their treatment effects are similar to the conventional techniques and few of them offer superior results in terms of reduction in post operative pain, bleeding and enhances rate of tooth movement. Adequate knowledge on the type of treatment required and the type of LASER that best suits the procedure will help in achieving better results.

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