ORIGINAL RESEARCH PAPER
Volume - 10 | Issue - 07 | July - 2021 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr
INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

APPLICATIONS OF LASER IN ORTHODONTICS - REVIEW

Orthodontics

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ABSTRACT

Lasers have been widely used in dentistry for more than thirty years and also has a wide range of applications in both hard and soft tissue in the field of orthodontics. They provide many benefits such as acceleration of tooth movement, pain control, bloodless field, reduction of treatment duration, improved esthetics, enamel etching, bonding and debonding of brackets, gingivectomy and frenectomy etc. Major disadvantage is its high cost. This review article emphasis on the various applications of lasers in orthodontics and provides an overview of laser physics, its classification, effects and types.

KEYWORDS

Laser, dentistry, orthodontics

INTRODUCTION

Laser is a device that aids in the production of light by converting electrical energy into optical energy. Laser light at particular wavelengths is produced by stimulating the atoms or molecules to the higher energy level thereby releasing their energy in phases that produces a very narrow beam of radiation. It Is nearly parallel, monochromatic and coherent beam of light that is opposite to ordinary lights[1].

LASERS conceptual basis was postulated by Albert Einstein. Einstein assumed that a photon could penetrate matter, where it would collide with an atom (PHOTOELECTRIC EFFECT). Since all atoms have electrons, an electron would be ejected from the atom by the energy of the photon, with great velocity [2,3].

In recent years, Laser (light amplification and stimulated emission of radiation) is considered to be the leading-edge technology in the field of dentistry because of their high-level precision that paves a way for the successful clinical procedures. The distinctive characteristics of LASERS can aid in provide an adjunctive support in performing procedures such as hemostasis, biological tissue ablation, painless oral soft and hard tissue surgeries [4].

HISTORY

YEAR	NAME	DEVELOPMENT OF LASER
1917	Einstein [5]	On the quantum Mechanics of Radiation
1954	Townes [6]	Invention of MASER
1958	Schawlow and Townes [7]	Invention of LASER
1960	Maiman [8]	Built the first working Laser
1963	Goldmann [9]	Introduced LASER into medical field
1964	Goldmann	Reported impact of LASER beam to dental caries
1964	Bell Laboratories	Developed Nd: YAG laser and CO2 laser
1980	Yamamoto and Sato [10]	Nd: YAG laser was first reported to be used in dental caries prevention
1989	Myers and Myers [11]	Development of a pulsed Nd: YAG laser.
1990-	Ho:YAG, Er:YAG, Argon, Er: YSGG and other types of lasers were invented and widely applied in dentistry	Laser has been widely applied in dentistry

CLASSIFICATION[12]

According to strength	According to their transmission system
Hard laser (used in surgical work) Co2 laser Nd: YAG lasers	Glass fiber systems-CO2 lasers
Argon lasers	Mirror system Nd: YAG lasers Argon lasers He-Ne lasers Diode lasers Q-switched Nd: YAG lasers
Soft laser He-Ne lasers Diode lasers (Used mainly for bio-stimulation and analgesia)	Both glass fiber and mirror system-pulsed excimer lasers

PROPERTIES OF LASER

Three unique properties of laser distinguish it from ordinary light [3]

a) Monochromaticity: The wavelength of light emitted by laser is very narrow compared to conventional light sources which emit light of a broad wavelength. Therefore, laser light has a single specific color instead of numerous colours.
b) Collimation: The beam of a laser has a constant direction, size and shape while conventional lights diverge in all directions.
c) Coherency: All the light waves are identical in laser light.

LASERS USED IN DENTISTRY [3]

CO_2 laser

ACTIVE MEDIUM – Gas -active and carbon dioxide
WAVELENGTH- 10600nm

CHARACTER- It has Highest absorption in hydroxyapatite and water

APPLICATION – It is used in soft tissue surgery and enamel surface modification

Nd: YAG Laser

ACTIVE MEDIUM- Solid active and it is a crystal of yttrium-aluminium -garnet doped with neodymium
WAVELENGTH- 1064nm

CHARACTER- It has good absorption in water and pigment tissue such as hemoglobin and slightly absorbed by dental hard tissue. It has good hemostatic ability.

APPLICATION- It is used in soft tissue surgery, sulcular debridement and to remove surface carious lesion.

Diode Laser

ACTIVE MEDIUM- solid active and solid-state semiconductor: aluminium, arsenide and gallium

WAVELENGTH- 800-900nm

CHARACTER- It is well absorbed by pigment tissue and water and poorly absorbed by dental hard tissue

APPLICATION- it is used in soft tissue surgery and sulcur debridement

Argon laser

ACTIVE MEDIUM- Gas active and argon
WAVELENGTH- 488nm,514nm

CHARACTER- 488nm is active camphoroquinone and 514nm absorbed by red pigment tissue and poorly absorbed by dental hard tissue

APPLICATION- It is used for curing composites, for sulcular debridement and in highly vascularized lesions

Er, Cr: YSGG and Er: YAG Laser

ACTIVE MEDIUM- Both Er, Cr: YSGG and Er: YAG is solid active. Er, Cr: YSGG is a crystal of yttrium-scandium-gallium-garnet doped with erbium and chromium and Er: YAG is a crystal of yttrium-gallium-garnet doped with erbium

WAVELENGTH- Er, Cr: YSGG -2790nm and Er: YAG- 2940nm
CHARACTER-It has highest absorption in water and has high affinity for hydroxyapatite crystals

APPLICATION- It is used in soft tissue surgery and tooth preparation

Ho: YAG Laser

ACTIVE MEDIUM- It is solid active and is a crystal of yttrium-aluminium-garnet doped with holmium

WAVELENGTH- 2120nm
CHARACTER- It has highest absorption in water and poorly absorbed by pigment tissue and dental hard tissue

APPLICATION- It is used in soft tissue surgery

BIOLOGICAL EFFECTS OF LASER

When laser comes into contact with the target tissue, it causes four types of interactions to occur [13,14]:

REFLECTION – It occurs when the laser beam redirects itself away from the target tissue surface without any interaction or penetration.

TRANSMISSION- It is usually seen in Nd: YAG and diode lasers. The laser energy penetrates the superficial tissues and interacts with deeper part of the tissues.

SCATTERING- Once it reaches the tissue site, energy released by the laser tends to transfer the heat to adjacent tissues or gets scattered in all directions. It weakens the laser energy and considered as undesirable.
ABSORPTION- absorption of laser energy by target tissue is considered as desirable. The tissue characteristics, emission mode and laser wavelength determine the amount of absorption.

PHOTOBIOLOGICAL EFFECTS OF LASER

PHOTOTHERMAL EFFECT [15,16,17]- It is produced by laser when it transforms light energy into heat energy. It occurs when the light energy is absorbed by chromophores which subsequently releases heat. Surgical incision, excision and coagulation are the results of photothermal effect.

PHOTOCHEMICAL EFFECT [15,16,17]- Chemical reactions within the tissue is initiated by generated photos. composite resin curing and disruption of chemical bonds are the result of photochemical effect.

PHOTOACOUSTIC EFFECT [15,16,17]- High power, short pulsed laser produces expansion of thermal molecules when it interacts with water in the tissue thereby disrupts the enamel and bony matrices by producing thermo-mechanical acoustic shock. This effect is considered as advantage in dental hard tissue procedures.

BIOSTIMULATING EFFECT [15,16,17]- It causes rapid wound healing, aids in increased collagen growth and produces anti-inflammatory effect and controls pain.

CLINICAL USES OF LASER

LASER ETCHING

Laser energy application can cause ablation and melting of enamel structure on the tooth surface [18]. This removal of superficial enamel structure (etching) occurs as a result of micro-explosion of water entrapped in the enamel, modifies calcium-phosphorous ratio along with the melting of hydroxy-apatite crystals. It produces micro-fissured surface and irregularities to a depth of 10-20 μm that depends on the energy and type of laser used [19]. Lasers such as CO2, Er: YAG, Nd: YAG, and Er, Cr: YSGG have been used for enamel conditioning before bracket bonding. Laser etching is considered as a promising method since it believed to have high caries resistance by producing acid resistant surface.

Lee et al [20] studied the effectiveness of Er: YAG laser of wavelength 2780-2940 in enamel conditioning and concluded that Er: YAG laser ablation can be an alternative to conventional etching before bonding procedure.

Fuhrmann et al [21] concluded that CO2 and Nd: YAG dental lasers produce good enamel conditioning and sufficient bond strength required for bracket bonding. They also stated that CO2 laser produces craters of various dimensions, while the Nd: YAG laser produces honeycomb structures as same as that of acid-etch technique.

In another study by Ariyaratnam et al [22] stated that Nd: YAG laser exhibited microcracks and fissures on the dentin surfaces and concluded that this is not a suitable method for substituting dentinal acid etching.

Najafi et al [23] evaluated the shear bond strength of metal brackets to microhybrid composite restorations after different surface preparation techniques (etching, sandblasting, grinding and CO_2 laser irradiation) and concluded that CO_2 laser and Sandblasting provides greater bond strength compared to other methods.

Study by Cokakoglu et al [24] showed that Er: YAG laser parameters of 1 W (100 mJ and 10 Hz) or 2 W (200 mJ and 10 Hz) for enamel conditioning cannot prevent enamel demineralization even when used along with different adhesives.

Sallam et al [25] stated that the laser-etched group (1.5 W/15 Hz/Er: YAG laser) demonstrated clinically accepted bond strength and could be an alternative to conventional acid etching.

LIGHT CURING LASERS

Initiation of polymerization reaction of many adhesives are initiated by application of visible light. Camphorquinone and tertiary amine, a photo initiator system in adhesives activates at wavelengths between 460 and 480 nm (blue region of the visible light spectrum), with a peak at 468 nm. It has been found that at least 300 mW/cm^2 of light intensity is required for optimal curing of a 2-mm thick layer of resin composite [26]. The major disadvantage is that they require 20-40 seconds to set each bracket using the light cure unit.

Recent research was emphasized on the argon laser's ability to achieve photo polymerization of composite resins. The argon laser is monochromatic and emits light over a narrow band of wavelengths in the blue, green spectrum (457.9-514.5 nm), which makes it ideally suitable for polymerization of composite resin [27]. Talbot et al [28] stated that argon lasers can be used to bond orthodontic brackets, achieving bond strengths similar to those attained with conventional light curing resins.

Matini et al [29] stated that CO_2, Er: YAG, and Nd: YAG are the most common lasers in using ceramic brackets in orthodontics. The use of laser is considered as an effective method in different aspects of procedures for ceramic brackets, such as bonding, debonding, rebonding, and the elimination of the residual composite on the tooth surface.

LASER DEBONDING

In orthodontics, debonding procedure is considered as a major concern due to the fractures and cracks in the enamel surface [30]. Most commonly enamel fractures are encountered with ceramic brackets due to the increased bond strength [31]. Application of laser irradiation can soften the adhesive resin thereby helps in easy removal of brackets with applying light force.

The mechanism of laser debonding includes: thermal softening, thermal ablation or photoablation [32].

In thermal softening, the bonding agents is softened followed by thermal ablation process where the resin temperature is raised rapidly that cases vaporization and decomposition of material that causes the bracket to slip-off the tooth surface.

Different types of lasers (CO_2 [33], Nd: YAG [34], Er: YAG [35], Tm: YAG [36]), brackets (monocrystalline and polycrystalline) and adhesive materials (Methyl Methacrylate MMA and Bisphenol A-Glycidyl Methacrylate Bis-GMA) were compared to study the effects of lasers in bracket debonding. Most of the study stated that laser debonding is more time efficient and showed decreased enamel damage.

Sinaee et al [37] stated that the diode laser with either 1 W or 3 W power for 3 s is effective in debonding the ceramic brackets without any effect on the pulp or enamel, while another study showed that Er: YAG laser application along with water cooling during debonding appeared to be a safer option by reducing resin shear bond strength thereby reducing the likelihood of intrapulpal temperature increase.

ORTHODONTIC TOOTH MOVEMENT

Low level laser therapy (LLLT) accelerates the bone remodeling and causes changes in alveolar bone during orthodontic tooth movement. Changes in the osteoblastic and osteoclastic activity along with collagen formation has been reported in both pressure and tension sides. LLLT also plays major role in chondrocyte and fibroblastic proliferation, wound healing and bone regeneration. This is stated as "Biostimulating effect of LLLT" [38,39].

Based on the animal and clinical studies, LLLT has been demonstrated to increase the orthodontic tooth movement. Cruz et al [40] reported an increase of 34% of canine retraction within 60 days with fixed appliance. The group which received laser therapy moved 4.39mm comparing to the control group which moved 3.30mm. Another study by Kawasaki [41] showed a 1.3-fold more tooth movement in rat teeth which was irradiated by laser. some studies also reported a neglible or reduced tooth movement [42]. Goulart et al [43] stated that if the laser dose is low, it does not exhibit a biostimulating effect while higher dose can inhibit tooth movement completely.

Yamaguchi et al [44] reported that LLLT stimulated the velocity of tooth movement via RANK and c-Fms gene expressions that was further confirmed by his study in 2010 which showed increased stimulation of MMP-9, cathepsin K and integrin subunits after LLLT irradiation during orthodontic tooth movement in rats.

Hasan et al [45] found a statistically significant difference between the two groups (LLLT used and control groups) in the overall treatment duration and the levelling and alignment percentage at T1 was achieved after 1 month of treatment initiation and in T2 it was achieved after 2 months.

PAIN CONTROL

Tooth movement procedure is considered to be painful for first 7 days after the retraction force is applied [46]. LLLT 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 [47]. Pain relief mechanism of LLLT is not known. The analgesic effect of LLLT is believed to its anti-inflammatory and neuronal effect [48].

Studies [49,50,51] have been conducted to evaluate and compare the pain perception of patients with or without the Laser irradiation at different time intervals. Most of the studied showed pain reduction with LLLT in orthodontic treatment within first 3-7 days. Few studies also showed an insignificant difference in pain perception between patients with and without laser irradiation [52].

Irfan Qamruddin et al [53] evaluated the effect of a single dose of LLLT on spontaneous and chewing pain caused by elastomeric separators and they stated that LASER provides adequate pain relief by increasing blood circulation thereby removes the inflammatory mediators and enhance the cellular activities.

A study [54] where 40 patients undergoing orthodontic treatment were divided into the laser group (810-nm gallium–aluminum–arsenic diode laser in continuous mode with the power set at 400 mW and 2 $J \cdot cm^{-2}$) and control group and was found that the application of LLLT appears to reduce the pain and sensitivity of the tooth and surrounding gingival tissues associated with orthodontic treatment.

According to the results of a randomized clinical trial conducted by qumruddin[55], a single dose of LLLT (940-nm aluminum–gallium–arsenide [Al–Ga–As] diode laser set on continuous mode with the power set at 100 mW) considerably decreased postoperative pain followed by the placement of super-elastic Nickel Titanium wires for initial alignment and levelling.

SOFT TISSUE LASER

Soft tissue abnormalities such as gingival overgrowth, abnormal frenum and impacted teeth are commonly encountered problems before, during or after orthodontic procedures. Therefore, surgical procedures such as gingivectomy [56], gingivoplasty, frenectomy [57] and surgical exposure of impacted teeth [58] are most commonly performed.

Few studies stated that lasers can perform these operations with good precision, better hemostatic ability that aids in faster wound healing and less pain. Among various soft tissue lasers that were used for intraoral soft tissue procedures, diode, CO2 and Nd: YAG, are considered to be the most dominant ones. Recently, Er: YAG and Er, Er: YAG has been added due to their increased efficiency in soft tissue procedures [59].

To et al [60] compared the efficiency of laser-assisted gingivectomy (test group) and non-surgical periodontal therapy (control group) during fixed orthodontic treatment on patients with gingival hyperplasia and compared plaque index, gingival index, bleeding in probing, pocket depth, and gingival growth index and as a result gingival index, pocket depth, and gingival growth parameters, more significant level of improvement was found in the test group in early stages of the treatment.

LASER ASSISTED CIRCUMFERENTIAL SUPRACRESTAL FIBEROTOMY

One of the major reasons for the relapse after orthodontic tooth movement is supracrestal gingival fibril network. collagenous fibers complete their reorganizations within 4–6 months of time but elastic supracrestal fibrils remodel slowly and they are capable of generating enough force to move the teeth even after 1 year after the orthodontic treatment completion.

In RCT[61] that compared the tendency of conventional circumferential supracrestal fiberotomy (CSF) with Er, Cr: YSGG laser-aided CSF in against mandibular incisor's rotational relapse showed no significant difference between the two groups.

In a systematic review[62] that evaluated the efficacy of LLLT on relapse of corrected tooth rotations, it was concluded that the effect of LLLT is related to energy density where low-energy density appears to increase relapse and high-energy density reduces the relapse.

LASER WELDING

Orthodontic appliances are fabricated by joining one or various metal framework to achieve efficient treatment outcomes. Fusion of various metal components are achieved by soldering, welding or brazing. In recent times, lasers have been employed in welding. Crystals of YAG with added neodymium is mainly used for laser beam emission [63]. The advantages of laser welding include small focus point, no corrosion at the point and zero oxidation around welding zone.

LASER HAZARDS

According to guidelines provided by American National Standards Institute Z136.1-2007, there are four classifications (ranging from 1 to 4) of lasers based on its potential of causing biological damage to skin or eye by the reflected beam. Lasers that have been used in dentistry mainly fall into category-classes 3B and 4. Class 3B represents a maximum output of 0.5W which can even cause eye damage. Class 4

includes the lasers with high-power that are used in dentistry. There is no upper output limit, so lasers in this class will cause different injuries [64]. Therefore, practioners should be aware of the potential risks and hazards related to the lasers along with complete understanding of safety control measures.

The various types of hazards encountered within clinical practice includes
Ocular hazard
Respiratory hazards
Electrical shock
Equipment hazards
Tissue damage
Fire and explosion
Combustion hazards

CONCLUSION

Lasers are considered as an emerging trend in orthodontic modality as it used as the treatment option for many clinical conditions. Although they have many applications and advantages, it is necessary to determine the laser type and wavelength to meet all requirements in both soft and hard tissues. Laser systems also have some disadvantages, such as high cost, space requirements for some types, and high-risk potential for physician and patient if not used at the appropriate wavelength and power density. So before incorporating the lasers into the clinical practice, orthodontist must be completely aware of the basic science, safety protocol, and risks associated with them if not used properly.

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