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Review Article

LASERS IN ORTHODONTICS-A REVIEW

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ABSTRACT

Lasers have opened new vistas for the orthodontist and has influenced the orthodontic treatment in many aspects. The growing number of laser practitioners, propelled by the increasing body of evidence concerning the safe, effective, and appropriate use of lasers in dentistry, will continue to advance the application of Einstein's "splendid light" in their operatories, to the benefit of patient and practitioner alike. This review, thus aims to highlight the various applications of lasers in orthodontics.

INTRODUCTION

Mankind's fascination with the properties of light and its applications can be traced back to ancient times. Developments in physics at the beginning of the twentieth century laid the foundation for laser theory postulated by Albert Einstein, culminating in the invention of this special form of light in 1960 by Maiman.[1]

LASER is an acronym for "light amplification by stimulated emission of radiation". It is defined by three properties:

- Monochromatic (generates a beam of a single color or wavelength).
- Directional.
- Coherent (identical in physical size and shape).[2]

Commonly used lasers are Argon, CO_2, Diode, Nd: YAG (Neodymium: yttrium-aluminium-garnet), Er:YSGG(Erbium doped yttrium scandium gallium garnet), Er:YAG(Erbium-doped yttrium aluminium garnet laser).[1,2]

Components of laser

- Optical cavity-It is a compartment of mirrors that contains the laser medium. These mirrors act as optical resonators, reflecting the waves back and forth, and help to collimate and amplify the developing beam.[2]
- Medium-Lasers are generically named for the active medium. It can be gas, dye (in liquid), solid-state element (distributed in a solid crystal or glass matrix), or semiconductor (diode).The medium determines the wavelength and efficacy of the laser beam.[2]
- Pump-This stimulates the laser medium and includes electrical discharges, flash-lamps, arc-lamps, or chemical reactions.[2]

Emission modes

1. Continuous-wave mode-The beam is emitted at only one power level for as long as the operator depresses the foot switch.[1]
2. Gated-pulse mode-There are periodic alternations of the laser energy, similar to a blinking light.[1]
3. Free-running pulsed mode-Sometimes referred to as "true-pulsed mode". This emission is unique in that large peak energies of laser light are emitted for usually microseconds, followed by a relatively long time in which the laser is off.[1]

Tissue interactions and effects of laser

Depending on the optical properties of the tissue, the light energy from a laser may have four different interactions with the target tissue:

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1. Reflection-Beam is redirected off the surface with no effect on the target tissue.[1]
2. Transmission-Beam passes through the tissue with no effect on the target tissue.[1]
3. Scattering-This causes the photons in the beam to change directions. Scattering can also cause heat transfer to the tissue adjacent to the surgical site producing unwanted effects.[1]
4. Absorption-This is the usual desirable effect. The amount of energy absorbed depends on the tissue characteristics, such as pigmentation and water content, and on the laser wavelength.[1]

The following are the photobiologic effects of a dental laser:

1. Photothermal effect-In this the laser energy is transformed into heat. The three primary photothermal laser-tissue interactions are incision/excision, ablation/vaporization and hemostasis/ coagulation.[1]
2. Photochemical effect-This occurs when the laser is used to stimulate chemical reactions, such as the curing of composite resin.[1]
3. Photoacoustic effect-This is also called as spallation or explosive ablation. In this the laser energy is absorbed by water that builds the internal pressure increases in the hard tissue, with rupture of the mineral structure.[1]
4. Photobiostimulation effect-In this the laser is used in a non-surgical mode for modulatory effect on the tissues such as for analgesia and rapid wound healing.
5. Fluorescence-This occurs when certain biological pigments absorb the laser energy and emit a light of different wavelength.[1]

Laser energy and thermal effects on dental soft tissue.[1]

Tissue Temperature	Observed Effect
37-50	Hyperthermia; bacterial inactivation
>60	Coagulation; protein denaturation
70-90	Welding of soft tissue wound edges
100-150	Vaporization
>200	Carbonization; tissue charring

Applications in Orthodontics

Laser etching of enamel-Introduction of lasers has greatly simplified the bonding procedure. It has been suggested that laser etching creates remineralisation microspaces that traps free ions and produces a surface that is more acid resistant and less susceptible to caries.[3] Because water spraying and air drying are not needed with laser etching, time can be saved (Usümez *et al*. 2002, Lee *et al*. 2003).[4] Sawan *et al* found no significant differences between 2.5W laser irradiation and phosphoric-acid etching for direct bonding of orthodontic appliances.[5] According to Aglarci, laser conditioning with an Er:YAG system results in successful etching, similar to that obtained with acid.[6]

Although 1.5 and 2 W laser irradiation can be an alternative to conventional acid etching, 0.5, 0.75 and 1W settings are not capable of etching the enamel suitable for orthodontic molar tube bonding.[7,8]

Bonding to porcelain- A glazed porcelain surface is not appropriate for resin penetration and orthodontic bonding due to the physical properties of surface and the chemical properties of bonding resins. Recommended surface treatment methods (Eg-hydrofluoric acid) can be time consuming or even harmful to soft tissues. Laser eliminates the need to roughen the porcelain prior to bonding.[9]

Poosti compared the shear bond strength (SBS) of metal orthodontic brackets to porcelain following conditioning by Er: YAG (erbium-doped yttrium aluminum garnet, 2W and 3W for 10s) and Nd: YAG (neodymium-doped yttrium aluminum garnet, 0.8W for 10s) laser in comparison to conventional method (9.6% Hydrofluoric acid). The results revealed that Nd: YAG laser was an acceptable substitute for hydrofluoric acid while Er: YAG laser with the mentioned power and duration was not a suitable option.[10]

Laser curing of orthodontic adhesives-90% of the orthodontists use light cured adhesives in their practice as they offer the advantage of time and hence more accurate bracket placement.[11]However, laser curing is also a viable alternative to the visible light curing.

Hildebrand *et al* compared bond strengths after curing with the argon laser (10sec) and the conventional curing light (40 sec) in vivo and in vitro. They stated that the bond strength for argon laser curing is comparable to conventional light curing and is sufficient for clinical applications.[12] Elaut *et al* in their study concluded that the use of argon laser (250 mW, 10s) curing is superior to that of conventional light-curing with respect to bond failure and chair side time. However, the incidence of decalcification seems to be similar.[13] Tania *et al* claimed that on curing with Argon laser polymerization is four times faster than with conventional visible light.[9]

Laser debonding of ceramic brackets-Although superior to metal brackets as far as aesthetics is concerned ceramic brackets have a major drawback of being brittle which can cause enamel tear outs and pain during their removal. Lately, lasers are being increasingly used to facilitate the debonding of aesthetic brackets. Stein *et al* studied the influence of irradiation on aesthetic ceramic brackets with a novel 445-nm diode laser prior to debonding and concluded that laser irradiation prior to debonding of ceramic brackets significantly changes bonding failure in terms of less remaining adhesive. This is of clinical importance as the risk of enamel fractures and chair time can be reduced.[14]

Yassaei *et al* in their study concluded that laser-assisted debonding of ceramic brackets could reduce the risk of enamel damage, without causing thermal damage to the pulp.[15] Oztoprak *et al* used Er:YAG laser at 4.2 W for 9 sec on polycrystalline brackets before debonding and found statistically significant lower shear bond strengths in the laser group (9.52 MPa) as compared with the control group (20.75 MPa).[16]

Composite ablation post debonding- The objective of debonding is to remove the bracket and composite adhesive remnant and restore the surface as closely as possible to its pretreatment condition without inducing iatrogenic damage. However, the conventional mechanical methods of removing remnant composite can sometimes markedly damage the underlying enamel.[11] Chan and Dumore in their respective studies stated that residual composite can be easily and selectively removed using CO_2 laser with minimal damage to the underlying sound enamel.[17,18]

Diagnosis, prevention and treatment of white spot lesions (WSL)-The prevalence of WSL, based on post treatment evaluations only, ranges from 0 to 97%.[19]Laser can be used as a valuable tool for diagnosing (DIAGNOdent, DIAGNOdent pen) and assessing the severity, progression, and depth of white spot lesions during orthodontic treatment.[4]Various studies have also shown a prophylactic and preventive role of lasers with respect to WSL. The mode of action for the prevention of enamel decalcification by altering the crystalline structure of the enamel has been suggested. Blankenau *et al* found an average of 29.1% reduction in the depth of enamel decalcification with argon laser irradiation.[20]According to Noel *et al* brackets cured with the argon laser for 10 sec resulted in significantly lower mean lesion depth when compared with a visible light control.[21] Qiao also stated that Er,Cr:YSGG laser irradiation is effective for increasing the acid resistance of dental hard tissue.[22]

Accelerating tooth movement-One of the biggest challenges faced by orthodontists is the lengthy duration of treatment. Various invasive and non-invasive methods have been proposed for accelerating tooth movement and low level laser therapy (LLLT) is one of the most promising of them. Yamaguchi *et al* showed that LLLT accelerates the process of bone remodelling by stimulating MMP-9, cathepsin K, and integrin subunits of a(v)b3 expression during orthodontic tooth movement in rats.[23]

Cruz *et al* in 2004 was the first to carry out a human study on the effect of low-intensity laser therapy on orthodontic tooth movement. They showed that the irradiated canines were retracted at a rate 34% greater than the control canines over 60 days.[24] Mehta and Patil evaluated the efficacy of LLLT in reducing orthodontic treatment duration in a split mouth study and found a 30% increase in the rate of tooth movement was observed with the low-intensity laser therapy.[25] In another study done by Kau on 90 subjects, there was 1.12mm change per week in the test subjects versus 0.49 mm in the control group.[26] Having said this, there are a lot of contradictory results related to the LLLT. It seems to have a demonstrated efficacy, but further studies are warranted to determine the best protocols with regard to energy and frequency.[27,28]

Laser analgesia-Laser irradiation is reported to improve the peripheral circulation, oxygenate hypoxic cells, inhibit the production of inflammatory mediators (PGE2 and IL-1) and help remove noxious products. Thus, LLLT may play a role during the inflammatory process that occurs in orthodontic treatment. Other biological effects of LLLT include metabolic enhancement and acceleration of wound healing through stimulation of fibroblast formation.[29]

Fujiyama conducted a study to evaluate the clinical effect of CO_2 laser in reducing pain during orthodontic treatment. Separators were placed at the distal contacts of the maxillary first molars in 90 patients. Significant pain reductions were observed with laser treatment from immediately after insertion of separators through day four.[29]

Tortamano found lower mean scores for oral pain and intensity of pain on the most painful day in patients receiving LLLT. Also, their pain ended sooner. LLLT however did not affect the start of pain perception or alter the most painful day.[30] On the other hand Fukui found no significant pain reduction after LLLT.[31]

Temporomandibular joint (TMJ) discomfort-Temporomandibular disorder (TMD) is a collective term, characterized by symptoms involving muscles of mastication, TMJ and orofacial structures resulting from a dysfunction of the stomatognathic system. Current treatment of TMD is mostly conservative. However, laser is a promising alternative for the same.[1] Muscles contain a large amount of myoglobin, the main absorber of the laser energy. The clinical effects are seen in the form of increased bite strength, range of motion, and muscular relaxation.[32] Laser beam is directed over the external facial area for 3 minutes and then in the posterior oral cavity, where trigger points for pain are present.[1]

Growth modification-LLLT has been used for growth modification procedures owing to its various effects at the cellular level (osteoblastic proliferation, osteoclast differentiation, increase in alkaline phosphatse activity and osteocalcin gene expression).[33] Moawad *et al* studied the efficiency of Erbium-YAG laser as an assistant method to rapid maxillary expansion where patients in the laser group underwent mucosal-bony perforations along the midpalatal suture every month, for three consecutive months. The findings showed more significant changes in most maxillofacial components in the laser group after the expansion phase.[34]

Studies on rats have shown the increase of mandibular length with LLLT therapy.[9]

Frenectomy-The presence of a diastema between the upper central incisors may frequently be due to a profound insertion of the upper labial frenum. In these cases, to facilitate the closure of such a space and to avoid post-treatment relapse, it is useful to carry out deep resection of the frenum with incision of the transeptal fibres, and the use of the laser permits simple and rapid resolution without bleeding or the need for sutures.[35]

On the other hand a short lingual frenum can lead to ankyloglossia, difficulty in speech and abnormal development of dental arches. Laser may be considered a simple and safe alternative especially for children while reducing the amount of local anesthetics needed, the bleeding and the chances of infection, swelling and discomfort. No suturing is necessary in these cases, as healing occurs through secondary intention, and in the vast majority of patients there is no need for post-surgical antalgic treatment.[36]

In a study done by Patel *et al* on 20 patients (10 each treated with laser and conventional scalpel technique) with high maxillary frenum it was concluded that patients treated with the diode laser had less postoperative pain and required fewer analgesics as compared to patients treated with the conventional scalpel technique. Wound healing at 7th day and after 1 month for both the groups showed statistical significant difference with better outcome in the laser group.[37]

Operculectomy-Pericoronitis refers to inflammation of the soft tissue in relation to the crown of an incompletely erupted tooth.[1]The most common cause behind pericoronal inflammation is the entrapment of plaque and food debris between crown of tooth and overlying operculum. This is an ideal area for the growth of bacteria and is also difficult to keep clean.[38] Laser (CO_2, Diode) is a useful alternative for operculectomy because of its excellent hemostatic abilities.[39]Although this tissue can be removed with any wavelength of laser, if chosen, the erbium laser must not contact the enamel, or a small area of hard tissue could be ablated. On the other hand the advantage of the erbium laser is that only topical anesthetic may be required.[1]

Gingivectomy and gingivoplasty- In certain cases during orthodontic treatment (crown lengthening, gummy smile, gingival proliferation, papilla flattening, asymmetric gingival zeniths) the gingival margin needs recontouring by means of gingivectomy/ gingivoplasty. However, the costs and postsurgical pain of this treatment might discourage patients. With the introduction of soft tissue lasers, which might be economic and less painful than conventional methods, the gingivectomy treatment became a routine part of orthodontic treatment. They provide hemostasis, reduce the infection risk, prevent damage to the teeth and bone and can incise the soft tissue to a depth of 2-6 mm.[40]

Access gingivectomies-These include access to partially erupted teeth, unerupted teeth, access for ideal bracket placement, uncovering of temporary anchorage devices, exposure of clinical crown before clinical impressions. Lasers improve the quality of orthodontic treatment delivered by allowing the procedures to be carried in a relatively painless manner with quicker healing.[1,35]

Pericision-Relapse after orthodontic correction of malocclusions is an undesirable but frequent experience. It could be due to unstable occlusion, changes related to growth, soft tissue pressure and periodontal and gingival fibers.[41] LLLT when combined with a retainer on the moved teeth may shorten the retention period by accelerating periodontal remodeling in the new tooth position.[9] Kim *et al* investigated the effectiveness of LLLT on orthodontically rotated teeth in beagles(Ga-Al-As diode laser) and it was concluded that laser pericision is an effective procedure to decrease relapse after tooth rotation, causing no apparent damage to the supporting periodontal structures, whereas LLLT on orthodontically rotated teeth without retainers appears to increase the relapse tendency.[42]

Advantages of laser

1. Coagulates blood vessels.
2. Seals lymphatics.
3. Sterilizes the wound during ablation.
4. Maintains a clear, clean, surgical field.
5. Markedly less bleeding.
6. Minimal swelling.
7. Less postoperative infection.
8. Precise incision control.
9. Reduced healing period.[42,43]

Disadvantages of lasers

1. High cost.
2. Requires expertise and training for use.
3. Retinal damage.
4. Cataract formation.
5. Skin blistering and burns.
6. Laser Plume(emission of noxious plume by laser vaporization of tissue).[43]

CONCLUSION

The dental practitioner who uses lasers must know their scientific basis and tissue effects, must receive proper training, and must have clinical experience. Although the types of tissue interaction overlap somewhat, each wavelength has specific qualities that will accomplish a specific treatment objective. Having said that, lasers have truly revolutionized the field of orthodontics. It has made it is possible now for orthodontists to more easily and ably address the challenges faced on a daily basis in clinical practice.[1,44]

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