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Laser Technology in Orthodontics: A Review

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ABSTRACT
LASER stands for 'light amplification by stimulated emission of radiation'.

For more than 35 years, dentists have been using laser systems. Laser systems offer numerous benefits, including enhancing patient cooperation, shortening treatment times, and assisting orthodontists in improving a patient's smile design to increase treatment efficacy & reducing orthodontic pain and discomfort. However, there are certain disadvantages which includes cost, large space requirements for some types of lasers, and high-risk potential for orthodontist and patient if not used at the appropriate wavelength and power density.

Lasers have many applications in orthodontics, including accelerating tooth movement, bonding and debonding processes, pain reduction, bone regeneration, etching procedures, increase mini-implant stability, soft tissue procedures (gingivectomy, frenectomy, operculectomy) photo-biomodulation & anti-microbial photodynamic therapy

Therefore, this article gives information about recent advances in lasers used in orthodontics

Keywords: *laser, dentistry, orthodontics, photo-biomodulation, anti-microbial photodynamic therapy*

1. INTRODUCTION

Orthodontics is a specialty that is constantly in demand of innovations, with academic and market research focused on finding efficient, comfortable, and biologically compatible treatment tools. Efforts have been directed towards improving the patient's experience and minimizing the side effects from orthodontic interventions.[1]

A laser is a concentrated source of energy that travels through a collimated tube at a single wavelength (or colour).[2] This technology uses the devices that emit a specific form of light (amplified by stimulated emission of radiation), & induces different reactions when interacting with biological tissues.[3]

When laser wavelengths reach the target area, depending on the optical characteristics of the applied tissue, different interactions such as reflection, absorption, scattering, transmission can occur.[4]

Additionally, a dental laser provides various photobiological effects, such as photothermal, photochemical, fluorescence, photoacoustic, or bio-stimulation.[5]

Therefore, this study provides an overview of systematic review of laser light therapies used in orthodontics.

HISTORY

1917	Einstein published an article on the quantum theory of radiation which is considered to be the basic concept of laser technology.[6]
1954	Townes- an American physicist, first amplified microwaves by stimulated emission. An acronym "MASER" which stands for Microwave Amplification by Stimulated Emission of Radiation was used to describe the device they invented.[6]
1960	Maiman built the first working laser with ruby as the active medium material.[6]
1964	Bell Laboratories developed the neodymium-doped yttrium aluminum garnet (Nd:YAG) laser and carbon dioxide (CO2) laser, researchers were able to extend laser technique to both hard and soft tissues in the oral cavity. Ruby laser was rarely used due to its large energy requirement and collateral damage to other adjacent dental tissues.
1980	Nd:YAG laser was first reported to be used in dental caries prevention by Yamamoto and Sato
1990	the use of laser in dentistry was limited being confined to a small group of clinicians, until the development of a pulsed Nd:YAG laser by Myers and Myers which allowed this technique to be widely used in general dentistry
1997	the United States Food and Drug Administration (FDA) approved the erbium-doped yttrium aluminum garnet (Er:YAG) solid-state laser for hard tissue surgery.[7]
1998	the first diode laser was approved for soft tissue surgery.[7]
Recent years	Holmium YAG, (Er: YAG) and erbium, chromium:yttrium-scandium-gallium-garnet (Er, Cr: YSGG) applied in the field of orthodontics.

COMPONENTS OF LASERS[6,7]

A laser device basically contains three major parts

1. An optical resonant which consists of more than two mirrors
2. An active medium (gas, dye, solid-state electronic device or semiconductor)
3. An external energy source (pump source).

CHARACTERISTICS / PROPERTIES OF LASERS [6,7,8]

Three unique properties of laser distinguish it from ordinary light.

I. Monochromaticity: In contrast with conventional light sources, which generate light with a wide wavelength, lasers emit light with a very small wavelength. As a result, laser light has a single colour

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

III. Coherency: All the light waves are identical in laser light

CLASSIFICATION OF LASERS[9,10]

Lasers have been classified in many ways such as:

I. According to the wavelength (nanometers)

a) UV (ultraviolet) range – 140 to 400 nm
b) VS (visible spectrum) – 400 to 700 nm
c) IR (infrared) range – more than 700 nm

Most lasers operate in one or more of these wavelength regions.

II. Broad classification

1. Hard laser (for surgical work)

a) CO2 lasers (CO2 gas)
b) Nd-YAG lasers (Yttrium-aluminum-garnet crystals dotted with neodymium)
c) Argon laser (Argon ions)

2. Soft laser (for bio-stimulation and analgesia)

a) He-Ne lasers
b) Diode lasers

III. According to the delivery system

a) Articulated arm (mirror type)
b) Hollow waveguide
c) Fiber optic cable

IV. According to the type of active medium used:

• semiconductor lasers (diode laser)
• gas lasers
• solid-state lasers
• fiber lasers

V. According to laser medium

E.g. Erbium: Yttrium Aluminium Garnet

VI. According to pumping scheme

a) Optically pumped laser
b) Electrically pumped laser

VII. According to operation mode

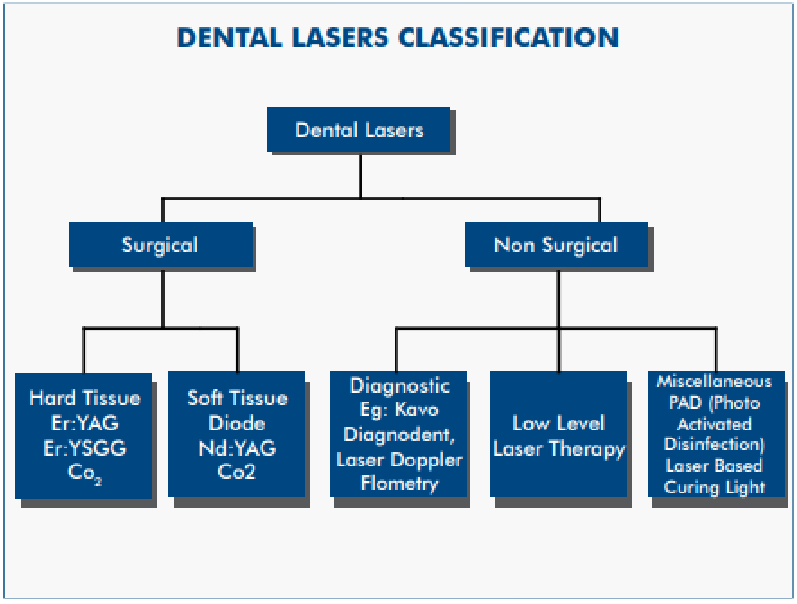
a) Continuous wave lasers
b) Pulsed lasers

VIII. According to frequently used low-level lasers and wavelengths:

- He–Ne: 633 nm

- InGaAlP: 633–700 nm
- GaAlAs (gallium–aluminum–arsenide): 780–890 nm
- GaAs: 940 nm.

IX. Based on the clinical use.[11]



FACTORS WHEN PLANNING LASER PROCEDURE IN ORTHODONTICS [12]

Three important factors that must be considered when planning most resective procedures:

a) the concept of biologic width

b) the level of keratinized tissue

c) pocket depth.

BIOLOGIC WIDTH→ The concept was introduced when Garguilo, et al. found that no matter how much tissue was removed, the distance from the height of crestal bone to the gingival margin adjusted to approximately 2.5 mm

KERATINISED TISSUE→ Attached gingiva is the portion of the gingiva extending from the free gingival groove, which demarcates it from the marginal (free) gingiva to the mucogingival junction, which separates it from the alveolar mucosa.

In order to minimize risk of gingival recession, it is usually best to leave a minimum of 1-2 mm of keratinized tissue in any gingival resection procedure.

POCKET DEPTH→ Healthy sulcus depth is approximately 1-3 mm

CLINICAL APPLICATIONS IN ORTHODONTICS

1. GINGIVECTOMY & GINGIVOPLASTY[7]

Gingivectomy is the surgical excision of a section of gingival tissue to enhance functional form, aesthetics, or oral health.

Gingivoplasty, which is typically performed in conjunction with gingivectomy, is the surgical reshaping and recontouring of the gingival tissue's outer surface for physiological, functional, or esthetic purposes.

Recommend laser settings: diode laser: 1.0–1.5 W; erbium doped solid-state laser: 1.5–2.5 W

2. FRENECTOMY[7]

Surgical removal of a small band of muscle tissue from its attachment into the mucoperiosteal covering of the alveolar process.

Individuals with thick & low labial frenum may result in midline diastema. Therefore, when a diastema is present, treatment often includes a combination of orthodontics and soft tissue surgery.

To make the procedure simpler and lessen the effect of scar tissue that could prevent space closure, labial frenectomy should only be done once the diastema has consolidated as much as possible.

Similarly, A short lingual frenum can cause "tongue-tie" or ankyloglossia. A short, thick lingual frenum that limits tongue movement is a characteristic of ankyloglossia, a developmental abnormality of the tongue.

Recommend laser settings: diode laser: 1.0–1.5 W, erbium doped solid-state laser: 1.5–2.5 W followed by coagulation at <1.0 W with no water

3. EFFECTS ON TOOTH MOVEMENT[13]

There have been several studies concerned with the biostimulatory effects of Lower Level Laser Therapy (LLLT). Most of the studies which have been investigated the effects of LLLT on tooth movement have been performed in animals.

The quantitative effects of a continuous laser (KLO3) and a pulsed laser (Optodan) on the orthodontic tooth movement of rabbits were examined by Seifi et al. According to the periodontal treatment regimen, teeth in this trial were exposed to radiation for nine days; a control group did not receive any radiation. Following therapy, the scientists found that LLLT decreased orthodontic tooth movement.[14]

In another study by Kawasaki and Shimizu et al, Rat molars were subjected to a 10 g orthodontic force, who then observed tooth movement in an experiment. The tooth's mobility was recorded after 12 days of irradiating the surrounding tissue with a Galium-aluminium, & arsenic (GaAlAs) diode laser. According to immunohistochemical analysis, the laser irradiation group experienced 1.3 times as much tooth movement as the non-irradiation group. The number of osteoclasts on the pressure side and the quantity of bone production and rate of cellular proliferation on the tension side were both much higher in the irradiation group, according to the scientists.[15]

Cruz et al. for the first time looked into the effects of LLLT on humans in 2004. Every 30 days, the 11 patients in the study had their canine teeth mechanically activated in the control group, which was half of the upper arch. In addition to receiving the same mechanical activation, the other half was exposed to diode laser radiation. The study's findings demonstrated that the side treated with LLLT experienced a noticeably higher acceleration of canine retraction than the control.[16]

4. REDUCING PAIN DURING ORTHODONTIC FORCE APPLICATION

For orthodontic patients, low-level laser therapy (LLLT), whose energy output is low enough to keep the target tissue's temperature [17] from rising above 36.5°C (normal body temperature), can be an effective analgesic therapy. Additionally, this kind of therapy has biostimulatory and non-thermal effects.

Numerous studies have documented the analgesic effects of Nd: YAG [18], He-Ne[19], and GaAlAs[20] diode lasers in lowering orthodontic discomfort. Additionally, it has been discovered that local CO2 laser therapy effectively lessens the discomfort related to orthodontic force applications.[21]

According to Tortamano et al., LLLT successfully reduces pain brought on by the first archwire's application, but it has no influence on the onset of discomfort following the first archwire's placement. Results show that LLLT lowers the frequency of discomfort following multibanding at 6 and 30 hours when compared to a control group. However, additional research in the literature has demonstrated that LLLT does not significantly lessen discomfort following archwire placement or separation. To sum up, induction of laser analgesia is a novel therapeutic approach with the benefits of non-invasiveness, ease of use, and the absence of known tissue responses.[22]

5. ENAMEL ETCHING DURING BONDING PROCEDURES

An effective alternative for conventional acid etching has been laser irradiation.[23]

An acid-resistant surface is created by laser etching. When dental hard tissues are exposed to laser radiation, the calcium-to-phosphorus ratio is altered, the carbonate-to-phosphate ratio is decreased, the amount of water and organic components is decreased, and more stable, less acid-soluble compounds are formed, which lessens vulnerability to acid attack and caries.[24]

The binding strength of orthodontic brackets following three distinct etching processes—acid etching, Er: YAG laser etching, and a combination of these two techniques was evaluated by Lee et al. The findings suggested that Er: YAG lasers could be a useful substitute for traditional acid etching.[25]

The efficiency of an Er, Cr:YSGG hydrokinetic laser system in etching enamel for direct bonding of orthodontic appliances was assessed by Uşümez et al. at two distinct power settings. According to the investigation, etching the enamel using the Er, Cr: YSGG system produced less predictable and poorer (but statistically comparable) bond strengths than acid etching with 37% orthophosphoric acid for 30 seconds. However, they discovered that laser etching was quicker and more useful.[26]

6. EFFECTS ON BONE REGENERATION

There are two main ways that laser irradiation might promote bone growth. The first is promoting the growth of cells, particularly osteoblast-line cells that formnodules. The second is promoting cellular differentiation, particularly to committed precursors, which raises the quantity of differentiated osteoblastic cells and promotes the growth of new bone.

According to Saito and Shimizu, during rapid palatal expansion, a GaAlAs diode laser (100 mW) can speed up bone regeneration in a mid-palatal suture. They contend that by speeding up bone regeneration in the mid-palatal suture, LLLT prevents relapse and shortens the retention period.[27]

Angeletti et al. assessed the impact of a GaAlAs laser (830 nm, 100 mW) on bone regeneration in the mid-palatal anterior suture. Therefore, the study indicates that early on in laser therapy, bone healing can be enhanced.[28]

7. BRACKETS DEBONDING

An efficient and secure method for removing appliances is provided by high-intensity lasers. The bond strength can be lowered by employing the right conditions, making it easier for orthodontic attachments to become loose.

For bracket debonding, several laser types have been described, including diode, Nd:YAG, CO2, Er:YAG, and Er,Cr:YSGG.[29,31]

The bracket can slide off the tooth surface which involves heating the bonding agent until it becomes pliable. Diode lasers are currently less expensive, but because they don't require water spray, care must be taken because of the temperature increase, which might damage pulp. Erbium lasers (F) and other lasers that work by photoablation are the most often utilized for bracket removal.[30,31]

ADVANTAGES

- Gingivectomy→ Reduced bleeding due to the laser's ability to coagulate blood vessels during surgery, leading to less intraoperative and postoperative bleeding.[31]
- Frenectomy→ Minimized damage to surrounding tissues due to the laser's precision, resulting in faster recovery and reduced swelling.[32]
- Excising lesions→Lower risk of infection as the laser sterilizes the area during the procedure, reducing bacterial contamination.[31]

DISADVANTAGES

- The high cost of laser equipment makes it less accessible for smaller dental practices and increases treatment costs for patients.[33]
- Limited penetration depth in soft tissue surgeries can restrict the laser's effectiveness in certain procedures.[34]
- Requires specialized training for dental practitioners, which may limit its widespread use in some clinics.[32]

RECENT ADVANCES

A. PHOTOBIOMODULTION (PBM)

Because orthodontic appliances have a major impact on patients' dental health-related quality of life, orthodontists and patients are very concerned about the length of orthodontic therapy.

PBM accelerates tissue healing and reduces inflammation after surgeries such as gingivectomy or frenectomy.

PBM promotes osteoblast activity and supports bone regeneration in implantology.

PBM alleviates postoperative pain by modulating inflammatory responses and neural pathways.[35]

B. ANTIMICROBIAL PHOTODYNAMIC THERAPY (aPDT)

Maintaining proper oral hygiene due to the presence of orthodontic appliances has been a challenge in many patients & many a times which results in infectious diseases.

aPDT involves the application of photosensitizers to the affected area, followed by their activation using a specific wavelength of light. This process triggers a reaction that generates reactive oxygen species at levels sufficient to reduce pathogenic agents without causing any toxicity to the host.[36]

LASER SAFETY[13]

According to the standards of American National Standards Institute and Occupational Safety and Health Administration, lasers are classified into four different classes based on potential danger, as follows:

Class I: Low-powered lasers that are safe to view

Class IIa: Low-powered visible lasers. They do not cause damage unless one looks directly along the beam for longer than 1,000 s

Class IIIa: Medium-powered lasers that are not dangerous when viewed for less than 0.25 s

Class IIIb: Medium-powered lasers that are dangerous when viewed directly along the beam for any length of time

Class IV: Dangerous high-powered lasers that can cause damage to the skin and eyes. Even the reflected or radiated beams are dangerous. It is necessary to take appropriate safety measures. Most of the lasers used for medical and dental purposes are in this category.

2. CONCLUSION

The use of laser technology in orthodontics is currently at a high level of growth and is expected to grow in the future. The public's demands for painless, non-invasive, and efficient orthodontic treatment are being met by laser therapy, a new vision and era in dentistry. Treatment planning and prognosis have been improved as a result of the growing use of lasers on both soft and hard tissue in the field of orthodontics. Laser promotes a simpler, quicker procedure with no discomfort, which lessens tissue damage.[37]

However, to get the best results, it necessitates expertise, experience, and a current scientific foundation, just like any other treatment method in the health sciences. Modern dentistry places a strong emphasis on the value of efficient safety protocols that reduce patient discomfort. Thus, it is essential that one of the primary goals of orthodontic therapy be the quality of life associated with dental health.[36]

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