IP Indian Journal of Orthodontics and Dentofacial Research 2022;8(2):83–89

Content available at: https://www.ipinnovative.com/open-access-journals

IP Indian Journal of Orthodontics and Dentofacial Research

Journal homepage: https://www.ijodr.com/

Review Article

Lasers in orthodontics-Current update

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ARTICLE INFO

Article history:
Received 05-03-2022
Accepted 05-04-2022
Available online 30-05-2022

Keywords:
Lasers
Orthodontics
Gingivectomy
Gingivoplasty
Frenectomy
Pain reduction
Lowlevel diode laser

ABSTRACT

Ever since the development of lasers in the 1960s and subsequent introduction to the medical and dental field, it has become a must-have armamentarium in the orthodontic and dental office. Lasers offer a wide range of applications in orthodontic practice with the advantage of safety, convenience, reduced postoperative pain & discomfort. Lasers have applications in soft tissue management, hard tissue management as well as in the manufacturing process of various orthodontic appliances.

1. Introduction

Orthodontic patients are now looking for more than correcting crooked teeth and an abnormal bite. They want optimal results in a short duration of time with minimal effort. To be successful in orthodontic practice, orthodontists not only have to provide the best dental and facial results but also deliver the aesthetic soft tissue results efficiently. Orthodontists face plenty of challenges in practice due to the detrimental effects of plaque accumulation and poor oral hygiene in non compliant patients. It gets very difficult to manage such patients with an already busy practice. There are numerous recent advancements in lasers that make it easy and convenient to be used in an orthodontic office that can accelerate treatment by reducing the number and length of appointments needed while providing superior results.

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2. Historical Background

In 1917, Einstein published an article on the quantum theory of radiation which is considered to be the basic concept of laser technology.[1] In 1960, Maiman built the first working laser with ruby as the active medium material.[1] Goldman in 1964 reported the impact of ruby laser on dental caries.[1] The results showed crater formation and dentine fusion along with the disappearance of dental caries. He published another case report in one year on the effects of beam impacts on teeth.[1]

2.1. Types of lasers

The following four dental laser instruments emit visible light:

1. Argon laser: blue wavelength of 488nm (no longer manufactured as dental surgical Instruments).
2. Argon laser: blue-green wavelength of 514 nm (no longer manufactured as dental surgical Instruments).
3. Frequency-doubled Nd: YAG laser, also called a potassium titanyl phosphate (KTP) laser: green

https://doi.org/10.18231/j.ijodr.2022.016

wavelength of 532 nm.

4. Low-level lasers: red nonsurgical wavelengths of 600 to 635 nm (for photobiomodulation) and 655 nm (for caries detection).

Other dental lasers emit invisible laser light in the near, middle, and far-infrared portions of the electromagnetic spectrum. These include photobiomodulation devices with wavelengths between 800 and 900 nm, as well as surgical instruments, as follows:

1. Diode lasers: various wavelengths between 800 and 1064 nm, using a semiconductor active medium of gallium and arsenide, with the addition of either aluminum or indium in some devices.
2. Nd: YAG laser: 1064 nm.
3. Erbium-chromium–doped yttrium-scandium-gallium garnet (Er,Cr:YSGG) laser: 2780 nm.
4. Er: YAG laser: 2940 nm.
5. CO2 laser: 9300 nm and 10,600 nm.[2]

2.2. *Applications of lasers in orthodontics*

There are numerous ways Lasers can be used,

1. Diagnostic-
   (a) Laser Scanning
   (b) Laser Holography
2. Soft tissue management-
   (a) Gingivectomy
   (b) Gingivoplasty
   (c) Laser Exposure of the superficially impacted teeth for bonding attachment
   (d) Other applications of the laser soft tissue procedures in orthodontics- frenectomy, operculectomy, circumferential fiberotomy, ablation of minor aphthous ulceration, excision of soft tissue lesions.
3. Low-level diode laser(Photobiomodulation)
   (a) Lasers for orthodontic pain reduction
   (b) Lasers for the acceleration of orthodontic tooth movement.
4. Other Applications-
   (a) Laser Welding
   (b) Laser etching
   (c) Lasers in caries prevention
   (d) Lasers in debonding[1,3–14]

2.3. *Diagnostic lasers*

2.3.1. *Laser scanning*

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.

Laser scanning also reduces the need for orthodontic plaster models and eliminates storage problems. G. De Luca Canto in his systematic review compared intra-arch dimensional measurement validity of laser-scanned digital dental models with the original plaster models and concluded that laser-scanned digital dental models are equally effective.[5]

2.3.2. *Laser holography*

Holography offers new non-destructive possibilities for bridging the gap between in vitro and in vivo measurements in dentistry, and thus increases the possibility of achieving more accurate and sometimes more objective diagnosis and therapy.[15] The use of stone and plaster study models is an integral part of any dental practice and is required for research.[15] Storage of study models is problematic in terms of space and cost.[15] Holography allows direct measurement of 3D displacements of a few micrometers.[15] The major problem with this technique is the poor quality of recording the details of the study models, particularly in the incisor region.[15] An advantage of holography is that films may be stored with medical records and it is a further step towards archiving dental study models.[15]

2.4. *Soft tissue management*

Lasers have been used extensively by orthodontists for soft tissue management in several clinical situations, some of these are listed below-

2.4.1. *Gingivectomy*

Orthodontic fixed appliances can be associated with chronic periodontal inflammation and gingival enlargement (GE) (Figure 1) due to increased plaque accumulation and poor oral hygiene. When GE further impedes the maintenance of oral hygiene (resulting in further damage to periodontal tissues), causes aesthetic and functional problems, and compromises orthodontic tooth movement, it is necessary to provide additional treatment such as gingivectomy, to correct gingival border contours. Gingivectomy can be performed by conventional scalpels, electrosurgery, chemosurgery, and laser (Figures 2 and 3). In a study comparing conventional vs laser gingivectomy in the management, of gingival enlargement during orthodontic treatment, authors have concluded that both methods are equally effective.[12] In terms of patient satisfaction, between conventional gingivectomy and laser-assisted gingivectomy, diode laser has a great advantage over conventional surgery in gingivectomy procedures.[7]

2.4.2. Gingivoplasty

Proportional gingival heights are needed to produce a normal and attractive dental appearance.[16] In general, the central incisor has the highest gingival level, the lateral incisor is approximately 1.5 mm lower, and the canine gingival margin again is at the level of the central incisor. Maintaining these gingival relationships becomes particularly important when canines are used to replace missing lateral incisors or when other tooth substitutions are planned. Both laypersons and dentists readily recognize differences of more than 2 mm.[16] For the best appearance, the gingival shape of the maxillary lateral incisors should be a symmetric half-oval or half-circle.[16] The maxillary centrals and canines should exhibit a gingival shape that is more elliptical and oriented distally to the long axis of the tooth.[16] The gingival zenith (the most apical point of the gingival tissue) should be located distal to the longitudinal axis of the maxillary centrals and canines; the gingival zenith of the maxillary laterals should coincide with their longitudinal axis.[16] Gingivoplasty is the surgical reshaping and re-contouring of the outer surface of gingival tissue for cosmetic, physiological, or functional purposes, usually done in combination with gingivectomy. With conventional scalpel surgery, gingivoplasty corrected the thick, unnatural gingival margins left after the gingivectomy procedure. With soft tissue laser surgery, gingivectomy and gingivoplasty are almost always used simultaneously to improve gingival health and enhance smile esthetics.[3]

2.4.3. Frenectomy

The labial frenum is a membrane that stretches along the midline from the internal surface of the lip to the alveolar mucosa. Among other functions, it limits lip movement, stabilizes the midline, and prevents unnecessary exposure of both alveolar mucosa and gingiva (Figure 4).[9] The correlation between the upper lip frenum and interincisal diastema has caused upper labial frenectomies to be performed regularly as a preventive procedure until the mid-1940s.[9] Not long after that, clinicians started to realize that there was a tendency for attachment to gradually migrate from the palatal to the buccal aspect throughout life as a consequence of the alveolar growth and the eruption of incisor teeth.[9] Therefore, the current recommendation is to wait until the permanent canines erupt before proceeding to a frenectomy. Regarding high-intensity laser therapy surgical technique, after anesthesia and laser preparation stages, the lip should be stretched to allow for an anatomical assessment of the frenum.[9]

Laser irradiation starts from the central part of the frenum towards the sulcus until the redundant frenum tissue is removed. No suturing is required since a secondary intention healing will take place.[9] (Figures 5 and 6)

2.4.4. Fibrotomy

Fibroma (irritation fibroma, fibrous nodule) is a benign, asymptomatic nodular mass of dense fibrous connective tissue covered by squamous epithelium (Figure 7).[3] A fibroma is the most common abnormal growth in the oral cavity; the most common location is the buccal mucosa, likely a consequence of trauma from cheek biting.[3] When removing soft tissue lesions, the clinician should consider lifting the lesion away from the soft tissue with forceps to excise at the base. The patient may experience mild bleeding for 30 minutes following excision.[3] (Figures 8 and 9)

2.5. Low-level diode laser (Photobiomodulation

Lasers with power outputs of <500 mW are used in low-level laser therapy (LLLT) to provide biomodulation, wound repair and pain relief. This application involves two main uses including the acceleration of orthodontic tooth movement and the reduction of orthodontic pain.[1,8,11]

2.5.1. Lasers for orthodontic pain reduction

There is a body of evidence confirming that placement of orthodontic separators and initial aligning archwires induce pain that reaches peak intensity at approximately 24h. This pain caused by orthodontic treatment can affect patient's compliance and even force them to terminate treatments prematurely.[8]

Recently a systematic review was done to investigate the effect of LLLT on the pain induced by orthodontic separator placement in which the wavelengths are the same (830 nm) and the methods are as much as possible similar to each other.[17] 299 studies were screened. 34 full-text papers were read by 2 authors independently. In the end, 4 articles met the inclusion criteria. All 4 articles showed LLLT has a significant impact on pain reduction. And they concluded that the exact protocol for laser therapy is still not clear. Therefore, more studies with a meticulously designed method are needed.[17]

Another systematic review by Mikael Sonesson et al investigated the scientific evidence to support applications of LLLT: (a) to accelerate tooth movement, (b) to prevent orthodontic relapse, and (c) to modulate acute pain, during treatment with fixed appliances in children and young adults. The quality of evidence supporting LLLT to accelerate orthodontic tooth movement is very low and low concerning modulating acute pain.[6]

2.5.2. Lasers for acceleration of orthodontic tooth movement

On the application of an orthodontic force, a rapid acute inflammatory tissue response is elicited.[8] The subsequent application of phototherapy apparently optimizes the cellular response permitting an increase in bone metabolism.[8] It is recognized, however, that higher doses of phototherapy can have an inhibitory effect on cellular metabolism.[8] However this will not result in tissue damage, provided the applied energy is kept below the level required to significantly heat the tissues to the point of protein degradation.[8]

Recently an article by Gayathri Ganesh et al[11] conducted a split-mouth single-blind interventional study. Which was carried out on 40 sites (18 patients) of both genders in the age group of 13 to 20 years requiring fixed orthodontic treatment with extraction of the first premolars in both or either arch. Segmental canine retraction was carried out using a nickel-titanium closed-coil spring. The laser side received low-level laser application and simulations were given on the opposite side on days 0, 3,7,11,15,28,31,35,39,43 and 56 post commencement of canine retraction.[11] A difference in the rate of tooth movement was observed to be 0.02 mm/day between the two groups with the laser side showing faster movement. The association between age and rate of movement in the laser group was negative i.e. the amount of tooth movement decreases with age. The authors concluded that Low-level laser therapy is effective in accelerating orthodontic tooth movement thus reducing the treatment duration with no association with age.[11]

Studies conducted in animal models using rats, dogs and rabbits have shown promise that laser and LED phototherapy can improve OTM.[4] A systematic review attempted to organize the existing published literature regarding tooth movement in orthodontic treatment when low-level laser therapy (LLLT) is applied. Studies in humans and animals in which LLLT was applied to increase dental movement were reviewed. Out of 84 studies, 5 human studies were selected in which canine traction had been performed after removing a premolar, and 11 studies in rats were selected in which first premolar traction was realized. There were statistically significant changes in four human studies and eight animal studies. They concluded that varying the wavelength with a reasonable dose in the target zone leads to obtaining the desired biological effect and achieving a reduction of the orthodontic treatment time, although there are studies that do not demonstrate any benefit according to their values.[4]

A systematic review by Mikael Sonesson et al concluded that the results highlight the need for high-quality research, with consistency in study design, to determine whether LLLT can enhance fixed appliance treatment in children and young adults.[6]

2.6. Other applications

2.6.1. Laser welding

The dental industry without lasers is inconceivable right now. This captivating technology has outlasted other possible alternative technologies applied in dentistry in the past due to its precision, accuracy, minimal invasive effect as well as faster operating time.[10] Other alternatives such as soldering, resistance (spot) welding, plasma (torch) welding, and single pulse tungsten inert gas welding have their pros and cons; nevertheless, laser welding remains the most suitable option so far for dental application.[10] Laser welding is one of the very recent yet versatile techniques used in dentistry, which is capable of manufacturing good quality weld joints with remarkable consistency. It has offered greater advantages such as reasonable hardness, reduced heat-affected zone and toughness over other compatible technologies available so far.[10]

2.6.2. Laser etching

Phosphoric acid etching is the gold standard for etching the enamel in orthodontic treatment; however, the most important disadvantage of this technique is the demineralization of the enamel surface layer, making it susceptible to acid attacks and prone to caries, particularly in the area next to an orthodontic bracket.[12] In recent years, erbium family lasers (erbium: yttrium-aluminum-garnet [Er: YAG] and erbium, chromium-doped: yttrium, scandium, gallium, and garnet [Er, Cr:YSGG]) have been reported to be alternatives for the acid-etching technique for bonding orthodontic brackets due to their ability to ablate enamel and dentin since their beams are properly absorbed by water and hydroxyapatite crystals.[12] A recent study was done by Vahid Mollabashi et al to compare the effect of two types of laser irradiation (erbium, chromium-doped: yttrium, scandium, gallium, and garnet [Er,Cr:YSGG] and erbium: yttrium-aluminum-garnet [Er:YAG]) and acid etching on enamel demineralization and shear bond strength (SBS) of orthodontic brackets. They concluded that Er:YAG and Er,Cr:YSGG laser etching resulted in clinically acceptable SBS; therefore, apart from its other advantages over acid etching, it can be a good appropriate alternative for bonding of orthodontic brackets.[12]

2.6.3. Laser in caries prevention

With the use of CO2 (10600nm), Er,Cr:YSGG (2780 – 2940nm), a review article states that enamel and dentin show micro-cracks that are suitable for resin penetration.[18] 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.[18]

2.7. Laser debonding

Metallic or ceramic orthodontic brackets are bonded onto the tooth surface to induce orthodontic tooth movements.[14] At the end of orthodontic treatment with multibracket systems, the brackets have to be removed. The resulting enamel surface after the debonding procedure should be as close as possible to the pretreatment condition, without

Fig. 1: Preoperative view,gingival enlargement

Fig. 2: Post-operative view, Gingivectomy using diode laser

Fig. 3: Post-operative view, one week after healing,

Fig. 4: Pre-Operative view, High labial frenum

Fig. 5: Post operative view,frenectomy using diode laser

Fig. 6: Post operative view, after healing

Fig. 7: Pre operative view, Fibroma

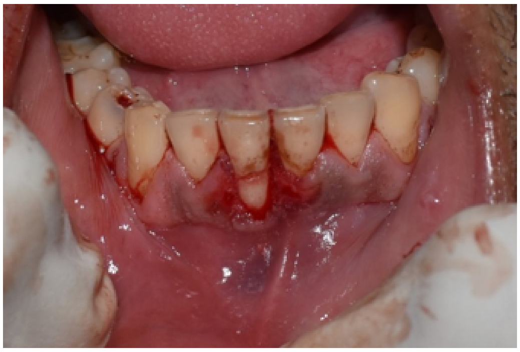

Fig. 8: Post operative view, after excision of the lesion using diode laser

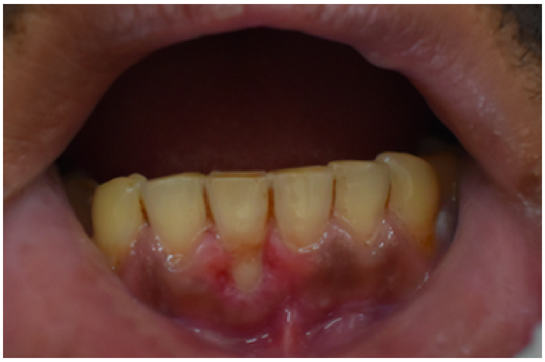

Fig. 9: Post operative view, after healing of the lesion

any iatrogenic damage. A recent paper by Thomas Knaup et al[14] assessing the effect of a 445-nm diode laser on the shear bond strength (SBS) of metallic brackets before debonding concluded that irradiation of metallic brackets with the 445-nm diode laser before debonding does not significantly reduce the SBS values and does not influence the remaining amount of adhesive on the enamel surface. The risk of enamel fractures during debonding is therefore not clinically affected. Similarly, a systematic review on ceramic bracket debonding by Ghazanfari et al concluded that laser irradiation is an efficient way to reduce shear bond strength of ceramic bracket and debonding time. This technique is a safe way for removing ceramic bracket with minimal impact on intrapulpal temperature and enamel surface and it reduces ceramic bracket failure.[19]

2.7.1. Lasers hazards and safety

Although most lasers used in dental practice are relatively user-friendly, precautions should be taken for securing a safe and effective operation. First, everyone subject to laser exposure should wear safety glasses — that includes dental professionals, assistants, patients, and any other people in the room (patient's family or friends, for example).[9] The safety glasses should be specifically chosen according to the laser wavelength. Although most lasers emit wavelengths that escape the visible part of the spectrum, their irradiation must not be neglected and caution should be taken. Besides the use of glasses, accidental exposure to laser beams can be avoided by signalling the risk areas with warning signs, limiting access to risk areas, minimizing reflective surfaces, and keeping the equipment under good operation conditions.[9]

3. Conclusion

Lasers are becoming a must-have armamentarium in the orthodontic and dental clinic with lasers being safe, convenient and easy to handle equipment. Lasers have a broad range of applications ranging from soft tissue laser-assisted procedures to recent applications on dental hard tissue and photobiomodulation. Although lasers have been proven to be very effective for soft tissue procedures however concerning photobiomodulation the data is still inconclusive in literature. More large-scale research with uniformity of samples is needed to conclude the effectiveness of photobiomodulation Lasers are increasingly used on large scale for manufacturing purposes such as welding bracket joints, in scripting numbering code on brackets etc. Keeping constant development, limitations, hazards and safety of lasers in mind, lasers can have a wide range of scope and convenience in orthodontic practice.

4. Acknowledgment

I would like to thank Dr. Priyanka Ray, PGT, Periodontics for providing pictures for various cases.

5. Conflict of Interest

The authors declare no relevant conflicts of interest.

6. Source of Funding

None.

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Cite this article: Khan R, Baruah N, Kashyap A, Bhattacharjee R. Lasers in orthodontics-Current update. *IP Indian J Orthod Dentofacial Res* 2022;8(2):83-89.