Lasers in orthodontics
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Abstract
The present era of modern dentistry revolves around the procedures and techniques that are convenient and patient friendly although the prime requisite is for advanced aids both in diagnosis and clinical procedures. The result of such quest has led to the introduction of light amplification and stimulated emission of radiation technique in both medicine and dentistry. This technique is currently being followed in all the specialties including orthodontics, where in it has resulted in a better and patient satisfaction practice, including decreased treatment timings and better results along with pain reduction procedures.

Keywords: Dentistry, light amplification and stimulated emission of radiation, modern orthodontics

Introduction
In this era of modern dentistry, the technical demands and level of precision required for successful performance of clinical procedures have traditionally been achieved by careful manipulation of hand instruments and by strict adherence to the biologic and surgical principles. One exciting technology making great inroads into lot of areas of dentistry today is the light amplification and stimulated emission of radiation (LASER) technology. The unique characteristics of lasers make it possible to perform treatment modalities beyond those available via conventional techniques that include ablation of biological tissues, hemostasis, pain relief and even hard tissue surgeries.[1] Because of the many advantages lasers are indicated for a wide variety of intraoral and extra oral aesthetic procedures, to treat both soft and hard tissues.[2] Laser technology can provide adjunctive support for clinicians engaged in periodontal and restorative treatment by making it possible to use conservative, minimally invasive procedures.[3]

History and Development
Laser, an acronym for “LASER,” is a device for generating high intensity, ostensibly parallel beam of monochromatic electromagnetic radiation. The possibility of stimulated emission was predicted by Einstein in 1917, based on the work of Gordon in 1955 and Schawlow and Townes in 1958. Theodore Maiman created a first operational laser in 1960, a ruby laser emitting a brilliant red beam of light, this was followed within 3 years by the development of argon, carbon dioxide, and neodymium: yttrium-aluminium-garnet (Nd: YAG) lasers, which remain the most widely used lasers in medicine (Tables 1-3).

Lasers in Orthodontics-Clinical Applications
Lasers in etching
Application of laser energy to an enamel surface causes localized melting and ablation and therefore removal of enamel.[4] Enamel removal (etching), results primarily from the micro explosion of entrapped water in the enamel, in addition there may be some melting of the hydroxyl-apatite crystals. Laser irradiation, in particular, causes thermally induced changes on the enamel surface. It causes surface roughening and irregularity similar to that of acid-etching to a depth of 10-20 μm, depending on the type of laser and the energy applied to the surface.[5] von Fraunhoufer et al. studied the effectiveness of a commercial Nd: YAG laser in etching dental enamel for direct bonding of orthodontic appliances. If a shear bond strength of 0.60 kg/mm is taken as
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Table 1: Classification of lasers

<table>
<thead>
<tr>
<th>Classification of lasers</th>
<th>According to strength</th>
<th>According to their transmission system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard laser (used in surgical work)</td>
<td>CO₂ laser</td>
<td>Glass fiber systems-CO₂ lasers</td>
</tr>
<tr>
<td>Nd: YAG lasers</td>
<td>Argon lasers</td>
<td>Mirror system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nd: YAG lasers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Argon lasers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>He-Ne lasers</td>
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<tr>
<td></td>
<td></td>
<td>Diode lasers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q-switched Nd: YAG lasers</td>
</tr>
<tr>
<td>Soft laser (use for bio stimulation and analgesia)</td>
<td>He-Ne lasers</td>
<td>Both glass fiber and mirror system-pulsed excimer lasers</td>
</tr>
<tr>
<td></td>
<td>Diode lasers</td>
<td></td>
</tr>
<tr>
<td>Nd: YAG: Neodymium: yttrium-aluminium-garnet</td>
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<td></td>
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</tbody>
</table>

Table 2: Classification of lasers based on their clinical uses

<table>
<thead>
<tr>
<th>Laser type</th>
<th>Wavelength</th>
<th>Main current clinical uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon</td>
<td>488, 514.5 nm</td>
<td>Curing, soft tissue desensitization</td>
</tr>
<tr>
<td>Diode</td>
<td>800-830, 950-1010 nm</td>
<td>Soft tissue, periodontics</td>
</tr>
<tr>
<td>Nd: YAG</td>
<td>1064 nm</td>
<td>Soft tissue, periodontics, desensitization, analgesia, tooth whitening, and endodontics</td>
</tr>
<tr>
<td>Er: YSGG</td>
<td>2.79 μm</td>
<td>Hard tissue</td>
</tr>
<tr>
<td>Er: YAG</td>
<td>2.94 μm</td>
<td>Hard tissue</td>
</tr>
<tr>
<td>CO₂</td>
<td>10.6 μm</td>
<td>Soft tissue, desensitization</td>
</tr>
</tbody>
</table>

Table 3: Classification based on thermal interactions of tissue

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Tissue effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>42-45</td>
<td>Hyperthermia (transient)</td>
</tr>
<tr>
<td>&gt;65</td>
<td>Desiccation, protein denaturation and coagulation</td>
</tr>
<tr>
<td>70-90</td>
<td>Tissue welding</td>
</tr>
<tr>
<td>&gt;100</td>
<td>Vaporization</td>
</tr>
<tr>
<td>&gt;200</td>
<td>Carbonization and charring</td>
</tr>
</tbody>
</table>

the minimum acceptable value for clinical use, the findings of the study indicate that laser etching must be performed at the maximum power output of the American Dental Nd: YAG laser to achieve consistent surface conditioning.

Laser for de-bonding procedure

Lasers have been tried in both acid etching and de-bonding of brackets with promising results. This approach has been shown to be efficient for de-bonding, resulting in a decreased adhesive remnant index and a relatively small increase in pulp temperature. In particular, application of Nd: YAG and CO₂ lasers have shown satisfying results, and minimal side effects from the increase in pulp temperature. Strob et al. studied on the efficiency of using CO₂ and Nd: YAG lasers in de-bonding ceramic brackets from the enamel surface. Laser-aided debonding technique was found to significantly reduce the residual de-bonding force, the risk of enamel damage and the incidence of failure as compared with the conventional de-bonding techniques. Therefore, this method has the potential to be more a-traumatic (less painful) and safer (less risk of enamel damage) for the patient.

Light curing lasers

The extended placement time offered by light-cured adhesives allows more accurate bracket positioning. The major disadvantage of these adhesives has been the 20-40 s required to set each bracket with a curing light. Although the shear bond strength of light-cured adhesives is comparable to that of chemically activated adhesives, it increases dramatically between 5 min and 24 h after placement, with the bond strength at 5 min only 60-70% of the bond strength at 24 h could be achieved. BisGMA, the most common monomer in composite adhesives, is polymerized when one of the double bonds at either end of the polymer is broken and then attached to another BisGMA polymer. Recent research has focused on the argon laser’s ability to achieve photo polymerization of composite resins. Photo activated dental resins use a dike tone initiator such as camphorquinone and a reducing agent such as a tertiary amine to initiate polymerization. This photoinitiator system is very sensitive to light in the blue region of the visible light spectrum, with a peak of activity centered around 480 nm. The argon laser is monochromatic and emits light over a narrow band of wavelengths in the blue, green spectrum (457.9-514.5 nm), making it ideally suited to polymerize composite. Talbot et al. determined whether argon laser irradiation of enamel has concluded that argon lasers can be used to bond orthodontic brackets, achieving bond strengths similar to those attained with conventional light curing resins.

Using lasers for orthodontic treatment management and enhancing aesthetics

Orthodontic patients are interested in more than just “straight teeth.” They are interested in well-aligned, beautiful white teeth; ideal function and occlusion; ideal gingival esthetics; well-proportioned faces and gorgeous smiles. Furthermore, patients would like this to be accomplished in a reasonable amount of time. Recently, the Soft-tissue laser has gained attention as an effective tool to help manage treatment and enhance the esthetic outcomes.

Lasers in Orthodontics-Non Clinical Applications

Laser scanning

Laser scanners are capable of producing detailed models however, the scanning process requires the subject to remain still for a period of seconds to a minute or more while the scanner revolves around the subjects head, because the laser provides...
only the surface map and cannot provide color information for the texture map. A color camera that is registered with the laser scanner provides this information. In studies of laser scanning of plastic and plaster mannequin heads, investigators reported a 0.6 mm variance of localization in the three axes (x, y and z) when using pre-labeled anthropometric landmarks. Three-dimensional computerized data from a laser scanner can also be transformed using computer aided manufacturing and stereolithography techniques to produce orthodontic appliances such as splints, computerized wire bending, e-models, and surgical simulation models. The self-corrected mechanism of the laser scanner in adjusting for image distortion gives flexibility for clinical research. The software can be used to merge images taken from different perspectives, thus eliminating undercuts. Studies involving dental casts can be performed with ease because computerized 3D wire-frame diagrams allow models to be cut, superimposed, and measured in the computer. Measuring changes in area and length of curvatures gives more insight for many data sets (Figure 1a).

For craniofacial anomalies, various studies could be performed regarding cleft lip repair, asymmetrical facial growth, change of head shape, and nasal molding procedures (Figure 1b). It was found in all cases that the scanner produced more accurate measurements in height (x) and width (y) but less accurate measurements in depth (z). For intermolar width, the scanner tended to produce smaller values than the manual measurement, but it produced larger values when measuring palatal depth (Figure 1c).

Laser holography

A new tool for measuring tooth movement-laser holography offers an accurate, non invasive approach for determining movement in 3 dimensions. The stresses generated in the periodontal ligament when the crown of a tooth is subjected to a force have important ramifications for the study of orthodontic tooth movement and periodontal disease. In particular, the orthodontist desires to relate the force system applied to the teeth to the center of rotation and the magnitude of tooth displacement. Previously, tooth displacements have been studied from a number of approaches: (1) Analytical models, (2) physical models, and (3) direct measurement in vivo.

The effects of force on the supporting periodontium and, in turn, tooth movement have also been studied by constructing physical models in photoelastic plastic and analyzing photoelastically the stress distribution produced by the applied force. Unfortunately, the attempts at mathematical modeling by an analytical approach as well as photoelastic techniques have been limited by a number of oversimplifying assumptions, such as (1) the anatomy of the root, periodontal ligament, and alveolar bone were represented by idealized geometric forms, (2) the physical characteristics of the supporting structures were assumed to be homogeneous, isotropic, and linear, whereas the structures of interest here are nonhomogeneous, anisotropic, and nonlinear. Furthermore, in most instances the model was two-dimensional.

Laser welding

The joining of the metal framework is frequently necessary to create individual orthodontic appliances and to achieve efficient treatment procedures. Recent methods employed for joining metal frameworks is laser welding to weld dental alloys, crystals of YAG, with added neodymium are mainly used to emit laser beams. The advantages of laser-welding is-no solder, and thus no corrosion at the joint, small focus and an argon shielding atmosphere prevents the oxidation around the welding zone.

Laser specular reflectance

The non-invasive technique, laser specular reflectance, also uses a preselected area of the wire surface. The three-dimensional structure of this area determines the diffuse scattered part of the laser light impinging on the surface and thus the structure of the whole region is used to calculate the roughness of the wire. The drawbacks of the method are an exacting adjustment and the limitation to roughnesses smaller than the wavelength of the laser light used. It is impossible to identify a surface roughness that is beyond this limit and all doubtful cases have to be examined against another method.

Various Adjunctive Procedures in Orthodontic Treatment

Creating access for bracket placement

The diode laser can be used to remove tissue (gingivectomy and gingivoplasty) and provide access for bracket/band/button attachment. These procedures provide earlier attachment to teeth and can significantly reduce treatment times. Usually,
cuspids are the last teeth bonded due to their slow eruption, delayed passive eruption or impaction. The diode laser can be used to assist the clinician in avoiding these situations by directly attaching the bracket or placing a band (Figure 2).

**Establishing tooth proportionality**

Most clinicians position the brackets (directly or indirectly) either by measuring a prescribed distance from the incisal edge or visualizing and positioning the bracket in the center of the clinical crown. Both methods are acceptable and have performed adequately for many years. Problems with these bracket-positioning methods tend to arise when the clinical crown is not equal to the anatomic crown in length, a common finding in adolescent orthodontic patients. Measurement from the incisal edge may result in an acceptable occlusal outcome but may result in poor oral hygiene due to encroachment of the bracket on the gingival margin. Bracket position in the center of the clinical crown would be too incisal, resulting in unwanted incisor intrusion and reduction of the incisal display at rest and on smile (Figure 3). The diode laser can be used at the initial placement visit, prior to positioning the bracket, to improve the proportionality and allow the position of the central incisors to be maintained during smile.

**Oral hygiene**

Chronic poor oral hygiene in orthodontic patients results in gingival overgrowth, pseudo-pocket formation, and plaque-retention problems, usually resulting in increased treatment times, unsatisfactory patients and parents, and ultimately a less-than-desirable esthetic result. These problems are difficult to overcome by the patient alone, and are rarely resolved completely by using the traditional methods. The diode laser can be used to remove the pseudo-pockets, providing access for patients to improve their oral hygiene and also provide better access for topical fluoride application. This procedure can often be combined with gingival contouring for improved gingival aesthetics, and can be performed at any point during treatment or at the de-bonding visit itself (Figure 4a).

**Aphthous ulcer management**

The diode laser can be used in noncontact mode (1-2 mm away from the tissue) to irradiate the ulcer for approximately 30 s.
to administer, and having no known adverse tissue reactions. It is worthwhile to look into its potential applications in orthodontics.

Many researchers have reported that Nd: YAG, He-Ne, and Ga-Al-As diode lasers have analgesic effects for reducing orthodontic pain. Moreover, local CO₂ laser therapy has been found effective in reducing the pain associated with orthodontic force applications. Lim et al. concluded that LLLT effectively controls pain caused by the application of the first arch wire, but it does not affect the start of pain after the first arch wire is placed and does not alter the most painful day. According to findings, LLLT reduces the prevalence of pain after multi-banding compared to a control group at 6 and 30 h. On the other hand, some studies in the literature have shown that LLLT offers no significant pain reduction after separation or placement of archwires. In conclusion, induction of laser analgesia is a new treatment modality that has the advantages of being non-invasive, being easy to apply and to have no known adverse tissue reactions.

**Laser safety**

Dental practitioners should be aware of dental laser safety including not only an awareness of the potential risks and hazards related to lasers used, but also recognition of existing standards of care and a thorough understanding of safety control measures. The types of hazards that may be encountered within clinical practice of dentistry may be grouped as follows:

- Ocular hazard
- Tissue damage
- Respiratory hazards
- Fire and explosion
- Electrical shock
- Combustion hazard
- Equipment hazards.

**Conclusion**

Lasers have become a ray of hope in dentistry. When used efficaciously and ethically, lasers are an exceptional modality of treatment for many clinical conditions that dentists treat on a daily basis. We live in a world of change, be it in art, automobiles, fashion or interpersonal relationships. Dentistry is not far behind in this. Lasers are one of the advances, which have definite potential, but in the present era, a lot of effort has yet to be made both for hard and soft tissue laser procedures to find a single laser that can satisfy the needs of all dental procedures, to be cost effective, and at the same time to have long term clinical safety record.

**References**