REVIEW ARTICLE

Lasers in Orthodontics

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ABSTRACT

With the ever-changing field of dentistry, there has always been a quest to find procedures and techniques that are fast, more effective, convenient, and patient-friendly. With the introduction of light amplification and stimulated emission of radiation technique in both medicine and dentistry has brought a sea change in these fields. Lasers have numerous applications in orthodontics, including enamel etching, debonding, curing composite gingivectomy, frenectomy, operculectomy, papilla flattening, uncovering temporary anchorage devices, ablation of aphthous ulcerations, exposure of impacted teeth, and even tooth whitening. Laser surgery helps the orthodontists to enhance the design of a patient's smile and improve treatment efficacy. With the introduction of laser-guided holography, there has been an increase in the spectrum of the field. Before incorporating lasers into clinical practice, the clinician must fully understand the basic science, safety protocol, and risks associated with them. The purpose of this article is to provide an overview regarding the applications of lasers in orthodontics.

Keywords: Dentistry, Light amplification, Orthodontics, Stimulated emission of radiation

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INTRODUCTION

With the evolving world where technology is bringing sea changes in all field, dentistry and orthodontics are no exception. Technological advancement has led to the introduction of LASER technique in both medicine and dentistry. Laser is abbreviated as "light amplification by stimulated emission of radiation." Laser beam is a focused source of electromagnetic radiation or light energy which travels in a specific direction and all wavelengths of the laser light travel in single phase.

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HISTORICAL PERSPECTIVE

Albert Einstein, a pioneer theoretical physicist in 1917, first gave the theory of "stimulated emission." This emission made the lasers possible. The device called "maser" was invented by Charles Townes in 1954 when he demonstrated a working device using ammonia gas as the active medium that produced microwave amplification. Arthur Schawlow in the year 1958 proposed the operation of optical and infrared masers, or "lasers," a term first coined in the year 1957 by physicist Gordon Gould. The first laser was developed in the year 1960 by physicist Maiman.[1] In 1962, the first diode or semiconductor laser was developed by Robert Hall. Kumar Patel in 1964 invented the CO_2 gas laser. The erbium-doped solid-state laser (Er: YAG) was tested by Paghidiwala on dental hard tissue in the year 1985. In 1997, the Er: YAG solid-state laser for hard tissue surgery was approved by the USA Food and Drug Administration. In 1998, the first diode laser was approved for soft tissue surgery.[2]

PROPERTIES OF LASER

1. Monochromatic
2. Directional
3. Coherent.

COMPONENTS

Mainly the following three components are used:
1. The laser medium (sometimes referred to as a gain medium)
2. The pump source
3. The optical cavity or optical resonator.[2]

Laser Medium

The laser medium is the "active element" that can be a solid-state element (distributed in a solid crystal or glass matrix), or semiconductor (diode) a gas, dye (in liquid), and the medium determines the wavelength of the laser.

Pump Source

Pump source "stimulates" the lasing medium until light energy is emitted. For example, pump sources include electrical discharges, flash lamps, arc lamps, or chemical reactions.

Optical Cavity or Resonator

The laser optical cavity amplifies the light energy. The optical cavity is a compartment of mirrors that contain the laser medium. Light energy released from the laser medium is reflected by the mirrors back on to itself, where it may be amplified by stimulated emission before exciting the cavity.[2]

LASERS IN ORTHODONTICS-CLINICAL APPLICATIONS

Microlaser Welding

Since the size of product becomes smaller in electrical and electronics industries, so the joining of thin metal sheet has been required. The flexibility of process is important according to the accessibility in the case of small component. Fraunhofer Institute for Laser Technology ILT developed the SHADOW® welding technique, in which high-speed joining with minimal distortion is possible using a pulsed Nd: YAG laser by a non-contact process. The processing time is defined by the pulse duration of pulsed laser, and the processing length was determined by the combination of pulse duration and velocity of laser beam. The welded joints show a smooth surface compared to the spaced spot welding. Prof. Miyamoto *et al*. at Osaka University had reported the possibility of high-speed and high-quality welding by the use of a single-mode fiber laser. The small heat input in the case of thin sheet causes easy distortion. Hence, welding with low heat input is necessary to avoid the large distortion. A smaller beam spot from the single-mode fiber laser and the thin-disk laser can increase the intensity, which leads to the low-energy input into the work piece with high-speed beam scanning. The combination of microbeam and high-speed laser scanning offers potential advantages for thin metal sheet welding. The welding seam length can be relieved from the restrictions of pulse duration in SHADOW® technique using the continuous wave (CW) fiber laser and the thin-disk laser. Therefore, the characteristics of microwelding for thin metal sheet were investigated by high-speed laser scanning, in which the welding was carried out by the scanner system with both single-mode CW fiber laser and pulsed Nd: YAG laser.[3]

ACCELERATING THE TOOTH MOVEMENT

Orthodontic tooth movement results because of bone remodeling where bone resorption and deposition occur in the compressed and stretched sides of the periodontal ligament, respectively. Various methods have been proposed to accelerate the tooth movement such as low-level laser irradiation, vibration,[4] pulsed electromagnetic fields,[5] pharmacologic agents,[6] and various surgical approaches, such as corticotomy,[7,8] osteotomy,[9] and dental distraction.[10] Low-level laser therapy (LLLT) has been used to accelerate the tooth movement in orthodontics induced by stimulating bone resorption and bone formation. The effect of LLLT in the root resorption process has been studied and shown that LLLT not only accelerates tooth movement but also may decrease the area and volume of root resorption craters that may occur and represent an undesired side effect of orthodontic treatments.[11]

DIGITAL SCANNING BY LASERS

Bolton analysis is universally employed to determine tooth size abnormalities for diagnostic and treatment planning purposes. In 1958, Bolton evaluated patients with ideal occlusions and established two ratios using the sums of mesiodistal widths of maxillary and mandibular teeth. Bolton analysis allows clinicians to determine tooth size discrepancy and the extent of difference from the ideal ratio. With increasing acceptance of digital dental technology, digital study models are becoming more popular in orthodontic settings. The ability of digital model technology to offer efficiency and convenience for practitioners, as compared to traditional physical study models, is stimulating more rapid and wider adoption of this technology in orthodontic clinics and institutions.[12]

ENAMEL ETCHING

Application of laser energy to an enamel surface causes localized ablation. Enamel etching results from the microexplosion of entrapped water in the enamel, and in addition to microexplosion, there may be some melting of the hydroxyapatite crystals. Laser irradiation mostly causes thermally induced changes on the enamel surface. The surface looks similar to that of acid-etched enamel. It also depends on the type of laser and the energy applied to the surface. Therefore, laser application is more atraumatic and safer (less risk of enamel damage) for the patient.[2]

GINGIVAL SHAPPING AND RECOUNTRING

Gingival reshaping can improve a gummy smile. It can greatly enhance the esthetic treatment outcome. The removal of excess gingival tissue by laser can permit the orthodontist to bond the bracket to the tooth in the desired appropriate position in a timely manner.[13]

TOOTH EXPOSURE

Soft tissues sometimes impede the eruption of the tooth into the arch. Laser can be used to remove the overlying tissue. Unerupted teeth should be visualized and located by radiographic images to determine if laser uncovering is warranted. Furthermore, for removal of operculum, sometimes the bonding of second molar becomes difficult if operculum is present. The diode laser can remove the operculum allowing immediate bonding on the desired tooth to keep teeth on track for timely eruption.[14]

FRENECTOMIES

Low frenum often contributes to excessive spacing. Such patients with a low frenum have a large central diastema. The soft tissue laser makes frenectomy procedures easier to manage than a traditional scalpel approach. Laser procedure is more homeostatic.[14] The use of soft tissue lasers offers many advantages such as improved oral hygiene, practice efficiencies, and esthetic finishing. When lasing tissue overlies a tooth, the operator must adjust the power as needed according to their tissue thickness. A bond can be placed immediately after tissue removal. Clinicians interested in incorporating soft tissue lasers into their practice should obtain proficiency certification, attend continuing education courses, and recognize the inherent risks associated with laser surgery. As an orthodontist committed to provide the best possible service, adjunctive procedures such as soft tissue surgery can dramatically enhance the overall treatment experience in your office.

DEBONDING OF CERAMIC BRACKETS BY A NEW SCANNING LASER METHOD

Within the past few years, ceramic brackets have gained popularity as the number of adult patients increase. Even though they have superior esthetic advantages compared with their metal counterparts, ceramic brackets can lead to problems such as enamel tear outs, bracket failures, and pain at removal because of their low fracture resistance and high bond strengths. Several debonding techniques including wood burning pens, warm air dryers, ultrasonic instruments, electrothermal devices, and lasers have been used to overcome problems during debonding. With these techniques, debonding is achieved by thermal softening of the adhesive resin by heat conductivity. Studies concerning this issue emphasize laser debonding, which is an effective way that works by controlling the amount of thermal energy delivered. Strobl *et al*. investigated the removal of polycrystalline and monocrystalline alumina brackets using carbon dioxide and YAG lasers. They used the laser beam shutter for the experimental setup, which had a thermally insulated fork to prevent fast cooling of the bracket. As soon as the laser beam shutter closed, a motorized translation stage pushed the mechanism for shearing off the bracket. Their results showed that laser-aided debonding significantly reduced debonding force by thermal softening of the resin. When the average torque force was considered, they found that monocrystalline brackets required less laser energy for debonding than polycrystalline brackets.[15]

REDUCING PAIN DURING ORTHODONTIC TREATMENT

Pain caused by orthodontic treatment represents an important clinical issue, often underestimated by the clinicians, but is considered extremely important by patients. Patients can forego orthodontic treatment because of pain, and the experience of pain during initial stage of therapy can negatively influence patients" cooperation and cause treatment interruptions. The pain sensation is a subjective experience dependent on physical and psychological factors such as gender, age, present emotional state, stress, cultural differences, previous pain experiences, and the magnitude of orthodontic force applied. Pain initiates 2 h after the application of orthodontic fixed appliance, raises over the next 24–36 h, starts to decrease on day 3, and disappears within 6–7 days. This nociceptive response is due to the compression of periodontal ligament inducing the release of algogens (i.e. prostaglandins, histamine, bradykinin, serotonin, and substance P), leading to delayed hyperalgesia. The nonsteroidal anti-inflammatory drugs (NSAIDs) commonly are administered to interrupt the algogens release and to reduce pain perception; however, there is some evidence that NSAIDs lead to the reduced rate of tooth movement. The analgesic efficacy of LLLT has been investigated leading to the proposal of several pain relief mechanisms, including the gate theory, the modulation of endorphin production, the anti-inflammatory effect, and the direct inhibition of neural activity. A number of studies have investigated the efficacy of diode LLLT also for orthodontic pain relief testing a CW LLLT; some authors concluded that LLLT did not significantly reduce orthodontic pain, while other studies found that it is effective for orthodontic pain relief. A recent literature review says that CW LLLT brings about an increase in tissue temperature and suggests that this adverse effect could be avoided by using a pulsed-wave LLLT. The principal characteristic of pulsed light is represented by pulse on and off periods. This allows shorter pulses and LLLT therapy with higher peaks of power compared to those allowed in CW mode lasers as well as reaching a deeper penetration depth and avoiding the unpleasant effects of CW (such as thermal damage).[16]

INCREASING BRACKET BOND STRENGTH

Adult orthodontic treatment requires bonding orthodontic attachment to dental restorations. Ceramics are commonly encountered as esthetic restorative materials for crowns and bridges. The orthodontist might not know whether the dental ceramic is feldspathic porcelain, aluminous porcelain, or glass ceramic. It is very common to find feldspathic porcelain in ceramic-fused-to-metal restorations. The physical and chemical properties of the glazed porcelain necessitate a multistep procedure, including deglazing of the porcelain or sandblasting, precise isolation, applying 9.6% hydrofluoric (HF) acid (HFA) for several minutes, and then rinsing, drying, and bonding. HF acid is found to be a harmful and irritating compound for soft tissues. Furthermore, the application of HFA is a time-consuming method. Hence, there is a need to find an alternative method for bonding brackets to the porcelain surface in the orthodontic practice. Roughening of the porcelain surface mechanically with diamond burs and sandblasting provokes crack initiation and surface damage in porcelain. Organosilane-coupling agents enhance the bonding of brackets to ceramic as it can act as mediator between the organic and inorganic matrixes of the porcelain. With the introduction of the ruby laser by Maiman in 1960, its various applications in dentistry have been increased. Different types of laser such as erbium-doped yttrium aluminum garnet (Er: YAG), neodymium-doped yttrium aluminum garnet (Nd: YAG), and Er,Cr: YSGG are been used in orthodontics for enamel conditioning to bond the brackets, and they all have shown acceptable results.

In recent years, CO_2 and Er: YAG laser are being used for porcelain conditioning, and because of the high power and wavelength of these lasers, destructive effects on the superficial layer of the porcelain have been shown. Li *et al*. prepared the porcelain surface with of 0.6-, 0.9-, and 1.2-W output power of Nd: YAG laser for bonding and concluded that this type of laser, in combination with light-cure composites, created acceptable bond strength to porcelain. Poosti *et al*. concluded that etching porcelain surfaces with Nd: YAG laser and 9.6% HF produced no significant difference in the shear bond strength of these methods, and Er: YAG with power of 2 and 3 W and surface roughening alone showed significantly lower bond strength than either the Nd: YAG laser or 9.6% HFA-etching treatment.[17]

RAPID MAXILLARY EXPANSION WITH LASERS

Animal model studies measured the formation and maturation of new bone qualitatively or quantitatively. LLLT seems to be a promising intervention for stimulating immediate bone regeneration and healing after midpalatal suture expansion. Studies done on animals measured the formation and maturation of new bone by means of immunohistochemistry qualitatively or quantitatively. Tissues taken from the midpalatal area of the non-irradiated and irradiated groups were sampled, stained, and analyzed with regard to bone neoformation by measuring osteoblasts and vessels or other molecular regulators of bone remodeling, such as growth factors and alkaline phosphatase. Only De Silva *et al*. combined immunochemistry with a pure quantitative expression analysis of genes that were related to bone repair, such as Runx 2, by real-time polymerase chain reaction. Even with the discrepancies in evaluation methods, these studies reported stimulatory effects of LLLT on bone regeneration after RME.[18]

CONCLUSION

Lasers are considered as "light in the end of the tunnel" in dentistry. It can be an exceptional modality of treatment for many clinical conditions when used effectively. Advantages of laser include improved oral hygiene and esthetic finishing as well. Lasers are one of the advances, which have definite potential, but in the present date, a lot of effort is still required for both hard and soft tissue laser procedures to find a single laser that can satisfy the needs of all dental procedures. As an orthodontist being committed to provide the best possible service, an adjunctive procedure such as lasers can dramatically enhance the entire procedure in one's dental office.

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