Lasers in Dentistry – An Overview

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Laser dental care is possible in all of the disciplines of dentistry. The public has an expectation that their dentist should be up to date and wants the most modern, advanced care possible. The future of lasers in dentistry is promising, and new applications and procedures are being developed. The public is made aware of this by various media, and the word “laser” has power because patients want and trust the doctors who offer advanced technology. Dentists and their staffs can successfully integrate the use of lasers into the everyday practice of dentistry. The clinician must be familiar with the fundamentals of laser physics and tissue interaction so that the proper laser device is used to obtain the treatment objective safely and effectively. Education, training, and marketing laser dentistry takes planning and time. The questions of fees, insurance involvement, and how offices will recoup the investment of lasers should be thoroughly planned and discussed. The pride and excitement of being on the cutting edge of dentistry and financial incentives make it more possible than ever to implement the use of lasers. “Clinical competence in any area of dentistry appears to require a combination of education and clinical experience.” This article features topics of laser science, tissue interaction, types & uses of lasers in dentistry that provide the foundation for the many applications of the use of lasers in dentistry.

Introduction

In 1960, Theodore Maiman, a scientist with the Hughes Aircraft Corporation, developed the first working laser device, which emitted a deep red–colored beam from a ruby crystal. During the next few years, dental researchers studied possible applications of this visible laser energy. Studies in the 1970s and 1980s turned to other devices, such as CO₂ and neodymium YAG (Nd:YAG), which were thought to have better interaction with dental hard tissues. The medical community in the mid to late 1970s had begun to incorporate lasers for soft–tissue procedures, and oral surgeons added the technology in the early 1980s. Since that time, numerous instruments have been made available for use in dental practice, and more are being developed.

The clinician should consider a number of factors when deciding whether to incorporate laser systems into their practices. First, they should realize that several types of lasers exist, with certain lasers approved for certain uses in dentistry and some lasers specific to soft–or hard–tissue applications. In addition, laser systems add significant cost to the delivery of care, requiring a sizeable investment in capital and the need to learn how to use the equipment. Dentists and patients also should realize that laser–induced tissue trauma to the surgical site can add several more days to the healing process. This article features topics of laser science, tissue interaction, uses of lasers in dentistry that enjoy the best scientific support, that provide the foundation for the many applications of their use in dentistry.

Laser–tissue interaction

The most desired interaction 1-3 is the absorption of the laser energy by the intended tissue. The amount of energy that is absorbed by the tissue depends on the tissue characteristics, such as pigmentation and water content, and on the laser wavelength and emission mode. In general, the shorter wavelengths (from about 500–1000nm) are readily absorbed in pigmented tissue and blood elements. Argon is highly attenuated by hemoglobin. Diode and Nd:YAG have a high affinity for melanin and less interaction with hemoglobin. The longer wavelengths are more interactive with water and hydroxyapatite. The largest absorption peak for water is just below 3000 nm, which is at the Er:YAG wavelength. Erbium is also well absorbed by hydroxyapatite. CO₂ at 10,600 nm is well absorbed by water and has the greatest affinity for tooth structure (Figure 1).

The wavelength of the light is the primary determinant of the degree to which the light is absorbed in the target material. Depending on the tissue, some lasers penetrate deeper than others. By contrast, other laser wavelengths are limited to a shallow penetration and have a surface effect on tissue. The deeper the laser energy penetrates, the more it is scattered and distributed throughout the
tissue. For example, the CO2 laser penetrates only about 0.03 to 0.1 millimeters into tissue. This provides just enough depth to seal blood vessels, lymph vessels and nerve endings measuring up to 0.5 mm in diameter. The clinical result of this penetration is good hemostasis and minimal postoperative morbidity. By comparison, the Nd:YAG laser penetrates 2 to 5 mm into tissue, it has caused concern about the risk of collateral damage in oral sites where bone and other hard tissue are within the range of energy.

Once the light from dental lasers is absorbed, it is converted to heat. The thermal effects of this heat depend, in large part, on tissue composition (that is, the amount of water and organic and inorganic components in the tissue) and the length of time the beam is focused on the target tissue. The duration of exposure results in temperature increases that may cause the tissue to change in structure and composition. These changes may range from denaturation to vaporization and carbonization, and even melting followed by recrystallization in the case of hard tissue. Dentists should also be aware that heat can be generated from the laser unit itself.

**Laser wavelengths used in dentistry (Figure 2)**

*Argon lasers:* Argon is a laser with an active medium of argon gas that is energized by a high–current electrical discharge. It is fiberoptically delivered in continuous wave and gated pulsed modes and is the only available surgical laser device whose light is radiated in the visible spectrum. There are two emission wavelengths used in dentistry: 488 nm, which is blue in color, and 514 nm, which is blue green. Acute inflammatory periodontal disease and highly vascularized lesions, such as a hemangioma, are ideally suited for treatment by the argon laser. The poor absorption into enamel and dentin is advantageous when using this laser for cutting and sculpting gingival tissues because there is minimal interaction and thus no damage to the tooth surface during those procedures. Dentists should be aware that, when used for resin curing, argon lasers do not necessarily produce a resin with physical properties superior to those of resins cured with traditional halogen curing lights.

*Diode lasers:* Diode is a solid active medium laser, manufactured from semiconductor crystals using some combination of aluminum or indium, gallium, and arsenic. The available wavelengths for dental use range from about 800 nm for the active medium containing aluminium to 980 nm for the active medium composed of indium. All of the diode wavelengths are highly absorbed by pigmented tissue and are deeply penetrating, although hemostasis is not as rapid as with the argon laser. These lasers are relatively poorly absorbed by tooth structure so that soft tissue surgery can be safely performed in close proximity to enamel dentin and cementum. Also, similar to an argon instrument, the continuous wave emission mode of the diode laser can cause a rapid temperature rise in the target tissue. The clinician should use air and sometimes water to cool the surgical site and to continue to move the fiber around the treatment area. The diode is an excellent soft
tissue surgical laser and is indicated for cutting and coagulating gingiva and mucosa and for sulcular debridement. Finally, within certain low–energy ranges, the diode laser can stimulate the proliferation of fibroblasts.\textsuperscript{19,20} 

\textbf{Nd–YAG lasers:} It can be used to perform a number of soft–tissue applications\textsuperscript{14–17}, including the following: gingival troughing; esthetic contouring of gingiva; treatment of oral ulcers. In addition, the Nd:YAG laser can be used to remove incipient enamel caries, although not as efficiently as can the Er:YAG, or Er,Cr:YSGG, lasers.\textsuperscript{18} The Nd:YAG laser also offers good hemostasis during soft–tissue procedures, which facilitates a clear operating field. The Nd:YAG laser has a number of disadvantages, however. It has the greatest depth of penetration of all the available dental surgical laser systems, which means that tissues under the surface are exposed to laser energy. This is cause for concern because of the risk of unwanted collateral damage, especially in the underlying bone or the dental pulp\textsuperscript{19,20}, as well as the associated postoperative morbidity. In addition, the diminished localization of the energy on the tissue’s surface makes vaporization of soft tissue with an Nd:YAG laser slower than with the better–absorbed laser wavelengths, such as those produced by the CO\textsubscript{2} laser. Pulpal damage (such as denaturation and disruption of the vascular and neuronal tissue) from this laser can occur, and is associated with a decrease in pulpal function (that is, sensitivity).

\textbf{The erbium family:} There are two distinct wavelengths that use erbium: Erbium, chromium:YSGG (2780 nm) has an active medium of a solid crystal of yttrium scandium gallium garnet that is doped with erbium and chromium and Erbium:YAG (2940 nm) has an active medium of a solid crystal of yttrium aluminum garnet that is doped with erbium. Caries removal and tooth preparation are easily accomplished by both the lasers. The Er:YAG laser\textsuperscript{21–32} It has a number of advantages. It produces clean, sharp margins in enamel and dentin. In addition, pulpal safety is not a significant concern, because the depth of energy penetration is negligible. When the Er:YAG laser is used for caries removal, the patient usually does not require local anesthesia. The laser is antimicrobial when used within root canals and on root surfaces, and it removes endotoxins from root surfaces. Finally, vibration from the Er:YAG laser is less severe than that from the conventional high–speed drill, and it is less likely to provoke discomfort or pain. The laser has shown potential for removing calculus during root débridement. On the downside, the Er:YAG laser does not selectively remove calculus on root surfaces.

The Er,Cr:YSGG laser\textsuperscript{33–37} It also has a number of advantages. The laser produces a rough surface in enamel and dentin without significant cracking. In dentin, no smear layer remains, which suggests good results with bonding. It is safe for the pulp. The disadvantages of the Er,Cr:YSGG laser involve the etching results. With this laser, enamel etching produces bonds with a wide range of strengths, which can be unreliable. To minimize leakage in resins, clinicians may need to acid–etch enamel after preparing cavities with the Er,Cr:YSGG laser.

\textbf{CO\textsubscript{2} laser:} It is a gas active medium laser that incorporates a sealed tube containing a gaseous mixture with CO\textsubscript{2} molecules pumped via electrical discharge current. The light energy, whose wavelength is 10,600 nm. This wavelength is well absorbed by water, second only to the erbium family. It can easily cut and coagulate soft tissue\textsuperscript{38,39} providing the dentist a clear operating field and it has a shallow depth of penetration into tissue, which is important when treating mucosal lesions. Postoperative pain usually is minimal to none. CO\textsubscript{2} laser also has some disadvantages. For example, wound healing can be delayed for a few days. Dentists should be aware that CO\textsubscript{2}–treated tissue will have a black/brown appearance, which is caused by a carbon residue that will easily rinse off within the first few days after the procedure. The exposed area can go through color changes for 10 to 14 days, eventually resulting in natural and healthy–looking gums.\textsuperscript{40}

\section*{Use of lasers on hard tissues}

\textbf{Lasers for caries detection}\textsuperscript{41–45}. While laser fluorescence has demonstrated good sensitivity and excellent reproducibility for detecting caries, it is not able to quantify the extent of decay. Laser fluorescence also has performed well in the detection of residual caries. While safety is not a concern with this low–power laser application, more data is required to aid in the clinical interpretation of the results and to develop a clinically useful sense of the limits of this technology.

\textbf{Lasers for removal of carious lesions and cavity preparation–} Laser systems can be used for effective caries removal and cavity preparation without significant thermal effects, collateral damage to tooth structure, or patient discomfort. Er–based laser system can achieve effective ablation at temperatures well below the melting and vaporization temperatures of enamel\textsuperscript{23,24,29}. To date, alternative laser systems, including super–pulsed CO\textsubscript{2}, Ho:YAG, Ho:YSGG, Nd:YAG, Nd:NLF, diode lasers and excimers, have not proven feasible for use for cavity preparation in general practice settings. Other than caries removal, this is a range of other well established laser hard tissue procedures include desensitization of cervical dentine (using Nd:YAG, Er:YAG, Er,Cr:YSGG, CO\textsubscript{2}, KTP, and diode lasers), laser analgesia (using Nd:YAG, Er:YAG, and Er,Cr:YSGG lasers), laser–enhanced fluoride uptake (using Er:YAG, Er,Cr:YSGG, CO\textsubscript{2}, argon, and KTP lasers).

\textbf{Laser Bleaching–} In October 1998, the ADA Council concluded that because of concerns regarding pulpal safety and a lack of controlled clinical studies, the CO\textsubscript{2} laser could not be recommended for tooth–whitening applications. The council indicated, however, that the argon laser might be an acceptable replacement for the conventional curing light if the manufacturer’s suggested procedures are followed carefully.

\section*{Use of lasers on soft tissues}

\textbf{Laser curettage–} Both the Nd:YAG and gallium–arsenide (or diode) lasers are promoted for curettage. A critical review of the best available evidence, however, strongly indicates that there is no added benefit to the patient when this procedure is performed after traditional mechanical
scaling and root planing. Proponents of laser curettage point to the ability of these lasers to kill microorganisms. Although the data indicate that this effect is possible albeit inconsistent, it has not been correlated with an improvement in periodontal attachment level. With no demonstrable benefit and with a significant risk of collateral damage to the periodontium, laser curettage appears to be neither scientifically nor ethically justified.

Er:YAG laser possesses suitable characteristics for various surgical and non-surgical procedures but randomized controlled clinical trials have to be encouraged to confirm its status as an adjunct or alternative to conventional periodontal therapy.

Summary and conclusion
There is a leaning curve in the use of lasers in dentistry. As long as the clinician has completed a training course & proceeds through the learning curve at a comfortable pace, the rewards will quickly be noticed by the patient and the dental team. Lasers can prove to be a blessing in disguise if used safely and properly.

References