

Soft-tissue lasers in orthodontics: An overview

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Soft-tissue lasers have numerous applications in orthodontics, including gingivectomy, frenectomy, operculectomy, papilla flattening, uncovering temporary anchorage devices, ablation of aphthous ulcerations, exposure of impacted teeth, and even tooth whitening. As an adjunctive procedure, laser surgery has helped many orthodontists to enhance the design of a patient's smile and improve treatment efficacy. Before incorporating soft-tissue 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 safe and proper use of soft-tissue lasers in orthodontics. (*Am J Orthod Dentofacial Orthop* 2008;133:S110-4)

Laser is an acronym for "light amplification by stimulated emission of radiation." A laser is a single wavelength (or color) of light traveling through a collimated tube delivering a concentrated source of energy. Most elements in the periodic system (atoms, gases, organic molecules, diodes, chemicals, or electrons) can be used as media to develop a laser beam.¹

In 1960, the first laser to use visible light (using a ruby medium) was developed by physicist Theodore H. Maiman,² after the theoretical work of Einstein, Basov, Prokhorov, and Townes.¹ In 1968, carbon dioxide was used to perform the first soft-tissue surgery. In 1997, the US Food and Drug Administration approved the erbium laser for hard-tissue surgery. The next year, the first diode laser with a medium of gallium, aluminum, and arsenide was approved for soft-tissue surgery.³

A laser offers numerous advantages compared with traditional scalpel surgery. Soft-tissue excision is more precise with a laser than a scalpel.⁴ A laser coagulates blood vessels, seals lymphatics, and sterilizes the wound during ablation, maintaining a clear and clean surgical field.⁵ Additionally, minor aphthous and herpetic ulcerations can be vaporized. Laser surgery is routinely performed by using only topical anesthetic, which is particularly beneficial in an open orthodontic clinic.⁶ There is markedly less bleeding (particularly for frenal surgery), minimal swelling, and no need for irritating sutures or unsightly periodontal dressing.⁷ A report sug-

gested that laser excisions produce less scar tissue than conventional scalpel surgery,⁸ although contrary evidence also exists.^{9,10} Postsurgically, patients report less discomfort and fewer functional complications (speaking and chewing), and require fewer analgesics than do patients treated with conventional scalpel surgery.⁷ The benefits of laser surgery are best summarized by Sarver and Yanosky⁵: "[Soft-tissue lasers] result in a shorter operative time and faster postoperative recuperation."

The primary disadvantage of laser surgery is the operator and upkeep expense. Some clinicians have reported greater tactile sense with a scalpel (which might be particularly true for noncontact soft-tissue lasers such as the erbium laser), tissue desiccation, and poor wound healing.¹¹

Lasers cut by thermal ablation—decomposition of tissue through an instantaneous process of absorption, melting, and vaporization.¹ Essentially, the cells of the target tissue absorb the concentrated light energy, rapidly rise in temperature, and produce a micro-explosion known as spallation.¹ Thermal ablation depends on the amount of light energy absorbed.⁴ The degree of absorption is determined by the wavelength (λ , measured in nanometers [nm]) of the laser, the electrical power of the surgical unit (measured in watts [W]), the time of exposure, and the composition of the tissues.^{1,4,6}

The optical fiber, or cutting end of the laser, is protected with an insulated layer that helps to collimate the light energy.⁴ Thus, ablation occurs only at the tip of the optical fiber. Attempting to cut from the sides of the laser will only drag the optical fiber against the gingival tissue, impeding tissue excision and damaging the laser tip.

Soft-tissues lasers deliver light energy in either a pulsed (gated) or a continuous mode. In the pulsed mode, periodic alternations of energy are created by a

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mechanical shutter that permits intermittent cooling of the tissues between pulses of light energy. Pulse energy is measured in millijoules (mJ) and can be adjusted on the laser display system. In the continuous mode, thermal relaxation does not occur, resulting in greater heat to the tissue. When greater coagulation is needed, either continuous energy or longer pulsed durations are desired to increase residual heat and seal open vessels.¹

DIODE AND ERBIUM LASERS

Currently, the 2 most popular types of lasers used in dentistry are the diode and the erbium lasers. Diode lasers (ie, Odyssey, Ivoclar Vivadent, Amherst, NY) are almost exclusively used for soft-tissue surgery. Erbium lasers (ie, WaterlaseMD, Biolase, San Clemente, Calif) can be used for hard- and soft-tissue surgeries. Each laser produces a different wavelength and has advantages and risks.

Diode lasers are semiconductors that use solid-state elements (ie, gallium, arsenide, aluminum, and indium) to change electrical energy in to light energy. Diode laser wavelengths ($\lambda = 810\text{--}980\text{ nm}$) approximate the absorption coefficient of soft-tissue pigmentation (melanin). Therefore, the light energy from the diode is highly absorbed by the soft tissues and poorly absorbed by teeth and bone.

Diode lasers are packaged in small, portable units (typically weighing less than 10 lbs). Connecting to the main unit is a thin, pencil-size handpiece containing a 400- μm lasing fiber. Before surgery, some diode lasers must first be conditioned or primed. Priming is the process of concentrating heat energy at the tip of the laser fiber.³ This is done by simply taping the fiber on articulating paper while the laser is energized.³ After the surgery, the end of the fiber (2–3 mm) is cleaved to expose a fresh tip. The glass fiber optic is scored and removed to prevent cross-contamination.¹²

During laser surgery with a diode, the fiber tip should be held in light contact with the tissue. Excision is performed with gentle, sweeping brush strokes.³ High-speed suction is helpful to reduce the slight charred odor and remove the laser plume.³ The tissues should have a light brown trim with minimal bleeding.

The advantages of the diode laser include the following: (1) they have excellent soft-tissue absorption and hemostasis; (2) it is difficult to damage hard tissues; (3) they can be used in contact mode, which provides tactile feedback; (4) they can be used for tooth bleaching; and (5) they are compact and low-cost (typically less than \$10,000).¹³

Erbium lasers are solid-state lasers based on the erbium ion (Er^{3+}). The ion is incorporated into a crystal matrix, which offers favorable mechanical and thermo-

optical properties.¹ The most common matrices are yttrium aluminum garnet (YAG) and yttrium scandium gadolinium garnet (YSGG). The 2 most common erbium lasers are the erbium-YAG and the erbium-chromium-YSGG. Comparative studies have shown little difference in efficacy between them.¹⁴ Erbium wavelengths ($\lambda = 2780\text{--}2940\text{ nm}$) can be absorbed by hydroxyapatite and water, and ablate both hard and soft tissues.¹⁵

Erbium lasers are packaged in larger, rolling units (typically weighing 80–90 lbs). The laser handpiece resembles a high-speed handpiece, with removable fiber-optic tips. The tips range from 400 to 750 μm and can be easily changed and autoclaved.

During surgery with an erbium laser, the fiber tip should be held 1 mm from the tissue.¹⁶ Excision is performed with slow, short back-and-forth strokes. Coagulation is achieved under a different setting, with low wattage and no water. An erbium laser can effectively control hemorrhaging, but strict hemostasis can be difficult because the laser operates in the pulsed mode.^{17,18} Tissues appear slightly reddish during excision and chalky white after coagulation.

The advantages of the erbium laser include the following: (1) priming is not required and (2) the fiber-optic tips are autoclavable. The primary disadvantage is the size and cost of the operating unit (approximately \$70,000). The main unit requires 80 psi of air pressure provided by an external source such as an operatory bay.

Electrical power, measured in watts, influences the depth of tissue penetration. For the diode laser, soft-tissue excision generally requires less than 1W of power. For the erbium laser, soft-tissue excision can require 1.5 to 2.5 W, depending on the tissue thickness; coagulation generally requires less than 0.75 W. An erbium laser ablates enamel at 4 to 5 W.^{14,18} Above 5 to 6 W, patients start to feel significant discomfort.¹ Strict adherence to the manufacturer's recommendations for unit settings should be followed.

Soft-tissue lasers both coagulate and produce a mild anesthetic effect during excision; as such, topical anesthetic to be used in place of local infiltration. The topical anesthetic should be highly viscous, include several active anesthetic agents to provide a wide spectrum of anesthetic action, and contain a vasoconstrictive agent.¹⁹ We advocate a topical mixture of lidocaine 20%, phenylephrine 2%, and tetracaine 4% (ie, TAC 20% Alternate, Professional Arts Pharmacy, Baltimore, Md). These topicals are contraindicated in elderly patients, patients with hypersensitivity to ester- and amide-type local anesthetics, para-aminobenzoic acid allergies, severe hypertension, hyperthyroidism, or heart disease.²⁰ To date, compound topical anesthetics, such as TAC 20% Alternate, are neither FDA regulated nor unregulated drug products.



Fig 1. Minimal marginal gingival regeneration: **A**, placement of topical anesthetic on a previously impacted canine with short clinical crown height; **B**, gingivectomy performed with an Er,Cr:YSGG, Waterlase; strict hemostasis with an erbium laser may be difficult; **C**, gingivectomy complete and tissue tag removed (photo taken immediately postoperatively); **D**, 3-month postsurgical follow-up with minimal marginal gingival regeneration.



Fig 2. Significant marginal regeneration: **A**, probing sulcular depths; large incisal fracture of the maxillary right central incisor was corrected with orthodontic extrusion and enamelplasty; **B**, external bevel gingivectomy, papilla flattening, and frenectomy (Er,Cr:YSGG, Waterlase shown); **C**, gingivectomy and frenectomy complete (photo taken immediately postoperatively); **D**, 3-month postsurgical follow-up. Notice the significant marginal gingival regeneration over the maxillary right central and left lateral incisors.

When applying topical anesthetic, (1) dry the mucosa with 2×2 gauze; (2) apply 0.2 mL (equivalent to 1 cotton swab head) of topical anesthetic to the mucosa for no longer than 5 to 7 minutes, because prolonged application can cause tissue irritation; and (3) confirm anesthesia with a perio probe, since peak anesthesia occurs after 7 minutes and lasts approximately 25 to 30 minutes.²⁰

Traditionally, a minimum of 1 mm sulcular depth of attached tissue was considered critical for maintenance of periodontal health and prevention of gingival recession. These opinions were based largely on the study by Lang and Löe²¹ on the significance of keratinized gingiva. However, more recent longitudinal studies have shown that, in the absence of gingival inflammation, the incidence of recession around teeth without attached gingiva

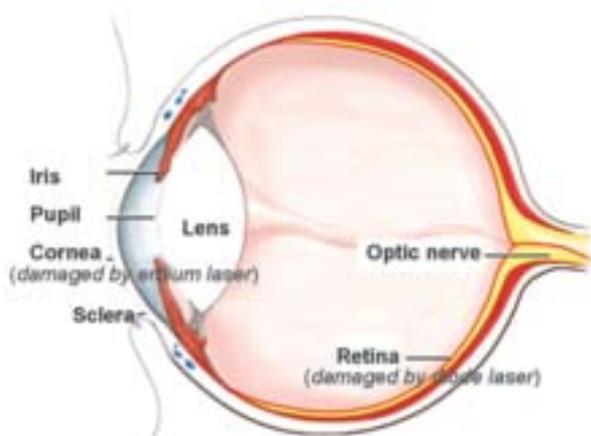


Fig 3. Eye anatomy and risks of laser surgery. Corneal damage can occur from an erbium laser, and retinal damage can occur from a diode laser.

was not greater than that observed in areas with attached gingiva.²²⁻²⁶ Experimental studies have even shown that gingivectomies extending into alveolar mucosa can regenerate as much as 50% with the formation of new attached marginal gingiva.^{27,28} Therefore, although the preservation of attached tissue is preferred, a certain quantity of attached gingiva might not be essential for maintenance of periodontal health^{29,30} (Figs 1 and 2).

PATIENT SAFETY

The clinician should perform ablation with the lowest possible energy. Higher energy will produce a higher ablation rate or speed of excision, but, if the energy is too high, it can cause unnecessary collateral damage. This is particularly true for the erbium laser, which can penetrate deeper into the dental hard tissue. Sarver and Yanosky⁴ recommended using a pulse mode with low wattage for all soft-tissue procedures.

The major concerns in laser surgery are exposure to laser radiation. Laser safety is regulated according to the American National Standards Institute's (ANSI) Z136 safety standards. ANSI laser safety standards are the basis for Occupational Safety and Health Administration (OSHA) and state occupational safety rules. All lasers sold in the United States since 1976 are classified according to their hazard potential. Currently, there are 6 laser hazard classifications (classes 1, 1M, 2M, 3B, 3R, and 4). Lasers used in medical therapeutic use, such as soft-tissue lasers, are class 4 products.

Class 4 lasers have an output power greater than 0.5 W. At this power, eyes and skin are endangered even at diffuse reflection. Protective arrangements must include creation of a danger zone, presence of a laser safety officer (the doctor), proper training of users, and consideration of fire hazards.



Fig 4. Recommended signs approved by ANSI and OSHA to be placed in the surgical danger zone and around the laser surgical unit.

Table. Dental codes for common soft-tissue procedures

Code	Procedure
D4210	Gingivectomy or gingivoplasty
D7960	Frenectomy
D7971	Operculectomy
D7465	Aphthous ulcer
D7430	Excision of benign tumor, diameter <1.25 cm
D7430	Excision of benign tumor, diameter >1.25 cm
D7286	Biopsy of oral soft tissue

The greatest risk of soft-tissue laser surgery is injury to an eye. The severity of injury depends on laser wavelength, distance from the laser, and power of the laser. The eye is precise at focusing light, and a split-second exposure to laser radiation can be sufficient to cause permanent injury. Retinal damage can occur at 400 to 1400 nm (called the retinal hazard region). The major danger is a stray laser beam reflected from a table, jewelry, or a belt. Diode lasers risk retinal burns and cataracts. Erbium lasers risk corneal burns, aqueous flare-ups, and infra-red cataracts (Fig 3).

Skin is the largest organ of the body and poses a high risk of radiation exposure. Skin can be penetrated at wavelengths of 300 to 3000 nm (both diode and erbium lasers), reaching a maximum penetration at 1000 nm. Arms, hands, and head are most likely to be exposed to laser radiation.

The patient and the clinician should be fully covered and wear protective goggles at all times. The goggles must block light at the appropriate wavelength and protect all possible (reflective) paths to the eyes. All nearby reflective surfaces should be covered or removed. Class 4 laser systems pose a fire hazard if the beam contacts flammable substances, and flame-retardant materials should be available. A discernable danger zone should be created around the surgical bay with a sign reading: "Warning: visible and invisible laser radiation. Avoid eye or skin exposure to direct scatter radiation. Class 4 laser product" (Fig 4).

Informed consent can vary, depending on the type of laser. Consent for the diode laser might include warnings

about mild bleeding, postoperative discomfort, and the need for surgical refinement. Consent for the erbium laser might include these additional risks: microcracks in the enamel, pulpal overheating, and tooth necrosis³¹ (although these risks are easily minimized by operating the laser at low wattage). Dental codes for common soft-tissue procedures are shown in the Table.

Immediately after the procedure, the patient should rinse with Listerine (Pfizer, Morris Plains, NJ) and gently massage the surgical area with a soft-bristle toothbrush. If tissue discoloration persists, hydrogen peroxide can be applied with a cotton swab or cotton roll. Bleeding and discomfort are minimal, except for a frenectomy, when minor bleeding is expected for 24 hours after surgery. Chlorhexidine and analgesics are rarely prescribed. Complete tissue healing takes place in 1 week. The patient should be seen for a postoperative follow-up after 2 weeks.

CONCLUSIONS

Diode and erbium soft-tissue lasers offer many advantages in regard to esthetic finishing, practice efficiencies, and interdisciplinary treatment options. Clinicians interested in incorporating soft-tissue lasers into their practice should obtain proficiency certification, provide proper staff training, attend continuing education courses, consider membership in the Academy of Laser Dentistry, and recognize the inherent risks of laser surgery.

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