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- Position Paper: Laser Safety in Dentistry
- Case Report: Soft Tissue Management During Implant Restoration
- Case Report: Removal of Porcelain Veneers
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The official journal of the Academy of Laser Dentistry

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This issue of the Journal contains a broad base of articles about dental lasers, describing clinical success as well as basic understanding about their interactions and safety. Three of the authors are recipients of the Academy of Laser Dentistry’s honors; the other writers describe principles of use that will help to achieve an optimum outcome.

Two highlights are descriptive clinical articles from both of the Leon Goldman Clinical Excellence Award winners from 2008:

- Dr. Giovanni Olivi, along with his wife Daniela, has written about the use of the dental operating microscope for exact visualization of a variety of laser procedures. The magnification gained by the microscope not only increases the visual acuity of the clinician during the procedure, but also clearly shows the benefit using a laser.

- Dr. Frank Yung offers a long-term clinical retrospective study of his use of an Er:YAG laser in periodontal surgery. Dr. Yung closely followed 60 patients for an average of 2.4 years, and reports on the treatment and results of four of them who exemplify the overall results.

Another highlight is from Dr. Arthur Levy, who received the Academy’s Distinguished Service Award in 2007. Dr. Levy provides his clinical protocol for periodontal therapy using a soft tissue laser adjunctively that has proved very successful for over the course of 15 years.

Additional features include:

- Dr. Michael Swick presents the first part of a two-part scientific discussion of laser-tissue interaction. His manuscript gives details about fundamental actions of how laser radiation affects dental tissues. The article is accompanied by a self-instruction program that is eligible for continuing education credit.

- Dr. Shawn Adibi presents a successful clinical procedure using an Er,Cr:YSGG laser for soft tissue preparation around an implant fixture for a final restoration.

- Dr. Alfred Wyatt describes his technique of using an Er:YAG laser to remove porcelain veneers that need replacement.

Also of significance is the Academy Position Paper on Laser Safety, written by the Laser Safety Committee (chaired by Caroline Sweeney) and adopted by the Board of Directors.

Lastly, I describe the proceedings of the joint meeting of the Academy and the U.S. Food and Drug Administration that was held in December 2008. The Academy’s team of presenters joined other speakers involved in research and development to offer information to interested parties as an opportunity to learn more about the present and future applications of lasers.

I hope you enjoy the information, and I hope to see you at ALD 2009 Conference and Exhibition in Las Vegas. As usual, I look forward to your submission of a manuscript that I can share with your colleagues.

**DISCLOSURE:** Dr. Coluzzi is a past lecturer for Hoya ConBio, a past and present presenter at American Dental Association, California Dental Association, Texas Dental Association, and other international organizations. He has no financial interest in any company.
A Dental Laser and a Microscope: The Perfect Match

Giovanni Olivi, DMD; Maria Daniela Genovese, MD, DMD, Rome, Italy

J Laser Dent 2009;17(1):6-12

SYNOPSIS
A laser and magnification play a fundamental role in contemporary dental practice, where a micro-invasive approach, precision, and esthetics produce the desired clinical results. The purpose of this article is to describe the advantages of the use of these high-technology devices in dentistry.

INTRODUCTION
The use of the Dental Operating Microscope (DOM) was introduced in the 1970s. At the start of the 1990s, it was used only in operating rooms. However, by 2000, the DOM was no longer used only by prosthodontists or endodontists, but could be found in many private practices of general dentistry.

Nd:YAG and CO2 surgical lasers were available at the start of the 1990s, erbium and diode lasers were introduced in the middle of the decade, and their usage increased greatly by 2000.

The use of high technology operative and diagnostic devices as well as an awareness of minimally invasive dentistry (MID) is gradually changing dental care. The concept of MID includes early diagnosis and minimal tissue removal. The common focus is tissue preservation, preferably by preventing disease from occurring and intercepting its progress; but also by removing the pathology with as little tissue loss as possible. MID is based on diagnostic procedures such as probing enamel fissures. In 1992 Penning and colleagues reported that the probing of fissures was not effective for detection of incipient decay, due to their complex anatomy. In 1998, a laser (DIAGNOdent, kaVo Dental GmbH, Biberach, Germany) was introduced for caries detection. The technology is based on the measurement of the difference in fluorescence of healthy and decayed tissues. The device detects occlusal caries at a level superior to what could be obtained with a bitewing X-ray, and has improved the sensitivity and specificity for diagnosis at the proximal aspect.

The use of high magnification and coaxial illumination along with dental lasers allows those who work with microdentistry techniques to diagnose and treat decay at the earliest possible stage, and to minimize the removal of healthy hard and soft tissues, with a more conservative result, as shown in Figures 1-4.

THE OPERATING MICROSCOPE IN DENTISTRY
Dentistry, like all branches of surgery, has always been considered as a manifestation of the fine motor and tactile skills of the individual operator. Use of either loupes or the microscope with coaxial illumination improves one’s visual acuity. Van As reported that, when magnification beyond 6X is used, the effectiveness of tactile inspection decreases, and that
many clinicians who use a higher-power microscope rely more on visual inspection.

Miniaturized instruments are needed in order to maintain the correct proportions between the magnified treatment area and the instruments being used, so that the operator has correct spatial orienta-
tion and ease of movement. In addition, the instruments should not obstruct the operating field. Figures 5 and 6 show examples of such instruments compared to conventional sizes; bur sizes compared to laser tips are shown in Figure 7.

The clinician who begins operating at high magnification will notice that small movements appear extremely large, and the authors have experienced unpleasant sensations from headaches to nausea while performing the treatment. With training, these movements can be calibrated into smaller ones with reduced proportions, evolving into motions as small as 10 to 20 microns. The authors have found that an operator's comfort will progressively increase, thanks to the ideal posture of the head, neck, shoulders, and back, as well as the arms and forearms which are maintained in position by special operating chairs with flexible armrests. The microscope can help to maintain a correct head position independent of the quadrant being observed (Figure
8), while loupes sometimes force the operator into incorrect posture, as shown in Figure 9.

Confidence in visual acuity will increase until it surpasses confidence in tactile sensation, with an increase in technical prowess with better clinical results. Figures 10 to 13 demonstrate an example of the excellent view that magnification can provide in a restorative procedure.

**THE OPERATING MICROSCOPE AND LASER DENTISTRY**

The DOM provides the clinician excellent visualization of laser-tissue interaction. Both contact and noncontact procedures benefit from the improved visual control which allows the correct aiming, focusing, and defocusing of the laser beam. For example, Figure 14 shows the proper placement of the optic fiber of a diode laser when viewed through the microscope.

The authors have found that they can more easily determine ideal laser parameters. Since power can be adjusted by focusing or defocusing the laser handpiece, magnification can verify the ideal working distance to the tissue. Moreover, the speed of movement of the beam is easily seen which could increase cutting efficiency and minimize collateral thermal damage. As an example, the well-defined incision in Figure 15 was accomplished by using a DOM.

Two clinical procedures will illustrate the benefit of magnification. A soft tissue lesion shown in Figure 16 can be excised as shown in Figure 17. The procedure can be carefully performed with very little tissue interaction. Both contact and noncontact procedures benefit from the improved visual control which allows the correct aiming, focusing, and defocusing of the laser beam. For example, Figure 14 shows the proper placement of the optic fiber of a diode laser when viewed through the microscope.

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**Figure 14:** View of beginning of soft tissue surgery to treat the fibrous mucosa covering the lower second molar. An 810-nm diode laser is being used (X4).

**Figure 15:** Incision for operculectomy continues. An 810-nm diode laser is being used with a 400-micron fiber, 1.8 W CW, in contact mode. Note the vaporization zone, the thin layer of necrosis (black), the surrounding blanching area (white), and excellent hemostasis (X4).

**Figure 16:** Papilloma-like lesion and anatomical contiguity with the salivary orifices (X10).

**Figure 17:** Excisional biopsy performed with an Er:YAG laser, 400-micron tip, 80 mJ, 20 pps, in contact mode. Note the absence of charring tissue, limited bleeding, and a small blanching area along with some warming of the bordering tissue (X4). The incision preserved the adjacent salivary tissues.

**Figure 18:** Complete healing after 21 days (X2.5).
disturbance of the surrounding healthy tissue, and healing is uneventful, as shown in Figure 18. Figure 19 shows the removal of a carious lesion with exposed pulpal tissue. Precise aiming of the laser energy produces coagulation, as shown in Figure 20, with minimal exposure of the beam to the adjacent dentin.

**HARD TISSUE THERAPY**

Traditional mechanical tooth preparation is performed with a bur in contact as an abrasive process. The erbium laser instead uses a photothermal interaction in noncontact mode, which varies from about a 1 mm to a 15 mm focal spot for different instruments. To ensure precision placement of the laser...
energy, the operator’s arms, elbows, and wrists should be in a stable position as shown in Figure 21, and the clinician’s fingers should rest on the teeth of the corresponding arch of the procedure (Figure 22). Also, the accurate aim of the beam can be facilitated by resting the head of the laser handpiece or the lateral part of the tip on the adjacent teeth, on the marginal ridge of proximal teeth for a Class II preparation, or on the edge of the cavity itself, as shown in Figure 23. Then, simple delicate movements of the handpiece will provide a change in inclination during the laser irradiation. Every movement of the patient is aligned with the movement of the operator’s hand so that the possibility of errant irradiation is easier to control, since small patient motions could produce large visual changes of the magnified operating area.

Some laser manufacturers provide tips that are 9-14 mm long, which improve the angle of vision without obstruction (Figure 24). Other manufacturers have realized that providing an angular handpiece or tip would work better for minimal interventions performed with the microscope. With these angled tips, it is also possible to interact with carious tissue in the undercut, or on the axial distal walls of the proximal cavities that are otherwise difficult to treat (Figure 25 and 26).

In the authors’ experience, after an initial training period and a learning curve from 6 to 12 months, it is possible to perform a dental procedure with laser technology and the operating microscope that is minimally invasive, simple, and safe. Again, two clinical cases illus-
tate this. Figures 27 to 29 demonstrate an apicoectomy procedure, and Figures 30 and 31 show the removal of two carious lesions and the finished preparation of the teeth with well-defined margins.

**SOFT TISSUE THERAPY**

All laser wavelengths perform soft tissue surgery; and, with the techniques described above, the DOM offers the clinician the ability to more precisely focus the energy onto the target tissue, whether in contact or in noncontact. The authors have found that it is possible to avoid charring or burning, to achieve coagulation when needed, to perform vaporization and contouring of the soft tissue, and to verify the exact position of the cementoenamel junction.

The last two clinical cases reinforce the benefits of magnification during laser treatments. The first shows how the Er:YAG laser was used to uncover an implant fixture as well as contour the soft tissue (Figure 32) so that a healing cap can be placed (Figure 33). The second shows an aesthetic soft tissue crown lengthening (Figures 34 to 37). The enamel surface was slightly ablated during the procedure but the follow-up photograph shows remineralization (Figures 37a and 37b). The DOM was a significant aid in determining the enamel damage and its subsequent repair.

During a frenectomy procedure, it is possible to check the vaporization that has occurred and the removal of the collagen fibers from the periosteum; controlling the energy and the focus avoids damage from overheating the periosteum tissue, permitting safe, predictable, and asymptomatic healing, as

![Figure 34: Preoperative view of two central incisors with a diastema, a conical tooth shape, and asymmetrical gingival alignment (X4)](image1)

![Figure 35: Immediate postoperative view after an erbium laser was used for tooth preparation and soft tissue crown lengthening. Composite resin was used to accomplish the closure of the diastema (X4)](image2)

![Figure 36: Magnification (X10) of the tissue shown in Figure 35. Note the limited bleeding but the unwanted etching of the enamel, due to an incorrect aiming of the erbium laser)](image3)

![Figures 37a and 37b: Very high magnification of the tissue shown in Figure 36 after 14 days of topical fluoride gel application (X40). The enamel has remineralized and the soft tissue has healed)](image4)

![Figure 38: Preoperative view of an insufficient width of attached gingiva due to orthodontic problems. The treatment plan is to revise the frenum’s insertion to limit the frenum’s traction on the marginal gingiva)](image5)

![Figure 39: Immediate postoperative view of the frenectomy performed with an Er/Cr:YSGG laser (X10). Magnification helps the complete and correct removal of all the collagen fibers so that the new attachment occurs on the mucogingival line. Note the absence of charring in the tissues)](image6)

![Figure 39: Immediate postoperative view of the frenectomy performed with an Er/Cr:YSGG laser (X10). Magnification helps the complete and correct removal of all the collagen fibers so that the new attachment occurs on the mucogingival line. Note the absence of charring in the tissues)](image7)

![Figure 40: Two-week postoperative view of the healed frenum attachment (X10). Note the scarred area that maintains the frenum in a lower position, without traction on the marginal gingiva)](image8)
shown in Figures 38 to 40.

**CONCLUSION**

The microscope combined with the use of a dental laser can produce several benefits for patients and clinicians.

Patients can be treated with therapies that preserve the most tissue and with beneficial postoperative sequelae, according to a minimally invasive philosophy of dentistry, thanks to the possibility of early diagnosis and conservative treatments.

Dental clinicians have the possibility of learning new operating techniques, and once the learning curve is completed, they can use the new technologies to improve their clinical results, expending less energy, and achieving more professional success.

The authors believe that together with the ongoing experimental research in new, improved operative protocols, it is also necessary to propose practical operating techniques to standardize dental practice, to improve both the therapies and the outcomes.

**AUTHOR BIOGRAPHIES**

Dr. Giovanni Olivi practices in esthetic and restorative dentistry in Rome. He is an active member of ALD, a founding fellow and Board member of the International Academy of High Tech, and an active member of the Italian Academy of Microscope Dentistry. He is a speaker in national and international laser conferences and an active member of the International Academy of High Tech, and an active member of the International Lasers in Dentistry. He is currently he is a consultant for Masters in Laser Dentistry at University courses in Genoa, Florence, and serves the same role for the European Master degree in Oral Laser Applications at the University of Nice and University of Parma. Dr. Olivi is the recipient of the 2007 Leon Goldman Award, presented for clinical excellence in laser dentistry from the Academy of Laser Dentistry. Dr. Olivi may be contacted by e-mail at olivi.g@tiscali.it.

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Dr. Maria Daniela Genovese practices in Rome and received her MD degree in 1985, followed by her DMD in 1989. She also received advanced training in Pediatric Dentistry and Orthodontics during that time and achieved a master’s degree in Gnathology and Posturology in 2001. She has been using dental lasers since 2000. Dr. Genovese is an active member of IAHT (the International Academy of High Tech) and of SIOI (Italian Society of Pediatric Dentistry). She is a national and international speaker and has authored and co-authored several articles on these topics. Dr. Genovese may be contacted by e-mail at olivi.g@tiscali.it.

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**BIBLIOGRAPHY**

The Use of an Er:YAG Laser in Periodontal Surgery: Clinical Cases with Long-Term Follow-Up

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SYNOPSIS
This article describes the treatment of 60 patients with periodontitis using an Er:YAG laser with a long-term follow-up of an average of 2.4 years. It is an uncontrolled study of clinical cases whose goal was to assess the effectiveness of the use of the laser. Representative examples of those cases will be shown.

INTRODUCTION
While the regimen of scaling and root planing (SRP) remains an essential part of any management of periodontal diseases, there are clinical situations in which the surgical excision of infected tissues or modifications of healthy structures is required after the initial mechanical debridement. Conventional surgical techniques, such as curettage, gingivectomy, full- or split-thickness flap, and other procedures, have been proven to be effective in treating moderate-to-advanced periodontitis, but the need to improve postoperative morbidity and control over-treatment outcome have provided the impetus to explore further for better surgical techniques and treatment alternatives. The principle behind laser surgery is the selective absorption of optical energy delivered by a specific laser wavelength to produce thermal effects on the target tissues to be excised or modified. The advantages of utilizing a laser for surgery over “cold steel” or electrosurgery are well documented in the literature, with some specific benefit differences among wavelengths. The overall recovery experiences and surgical results are so much more pleasant and predictable than those of conventional surgery so that for some surgical procedures, such as in the fields of ophthalmology, otolaryngology, and dermatology, the use of lasers have replaced other modalities in many instances.

During the 1960s and 1970s, different kinds of lasers with different wavelengths were invented, and they were studied subsequently for possible dental applications. Laser instruments, including carbon dioxide (CO₂), neodymium:yttrium, aluminum, garnet (Nd:YAG), argon, gallium arsenide (diode), and erbium:yttrium, aluminum, garnet (Er:YAG) were found to be effective for soft tissue surgery, including periodontics. The Er:YAG laser, which was developed in the early 1970s, also offered hard tissue applications.

The 2940-nm wavelength of the Er:YAG laser has absorption characteristics completely different from Nd:YAG, argon, and diode lasers; it is very highly absorbed by water and moderately so by dental enamel. This specific and selective laser energy absorption by water causes rapid micro-explosions of the water molecules.
initiated by the selective energy absorption within the target tissue, and provides the foundation for the water-mediated, photo-thermal-mechanical ablation of the Er:YAG laser.\(^\text{14}\) Whereas the optical energy is very strongly absorbed by the water molecules within the superficial layers of the target tissue, the penetration depth of this laser beam is limited to a few micrometers close to the surface. Based on this unique combination of strong superficial absorption and shallow penetration, tissues with high water content, such as dentin or gingival tissues, can be ablated or excised precisely by these micro-explosions with almost nonexistent thermal damage to the underlying tissues as long as there is proper water irrigation at the site.

An Er:YAG laser device was cleared for marketing by the U.S. FDA in 1997 for certain hard and soft tissue procedures, such as caries removal and cavity preparation, as well as incision and excision of intraoral soft tissues. Other Er:YAG laser instruments were then cleared for sulcular debridement in 1999, and in 2004 for osseous surgery. Animal studies have shown that this laser wavelength demonstrates suitability for vaporizing bone with minimal thermal damage and good postoperative healing.\(^\text{15-18}\)

While the use of this laser wavelength for dental hard tissue is relatively well-established in contemporary dentistry, there is some debate about its usefulness for soft tissue or periodontal procedures.\(^\text{19-20}\)

On the one hand, the Er:YAG laser’s radiation has been found to be strongly absorbed by many pathogenic bacteria that are related to periodontal infections,\(^\text{21-23}\) and it has been shown to be effective in removing root-bound calculus without damage to the cementum and dentin.\(^\text{24}\) Therefore, it has been studied for nonsurgical periodontal therapy, and significant gains in clinical attachments have been reported.\(^\text{19-25-27}\) However, for periodontal surgery, there are two common concerns for the use of this laser wavelength: (1) there is a lack of selective energy absorption between the target tissues and the contiguous nontarget tissues, such as the root and bone surfaces, and (2) the shallow energy penetration provides coagulation that is not as profound, and hemostasis is not concurrent with tissue ablation as the other soft tissue lasers, such as CO\(_2\), argon, diode, or Nd:YAG. The purpose of this study, therefore, was to evaluate these concerns clinically and determine whether the Er:YAG laser with full-time water irrigation was suitable for periodontal surgery in a safe and effective manner.

**MATERIALS AND METHODS**

In this study, 60 patients (33 males and 27 females with a mean age of 49 years) were treated for various periodontal conditions, such as acute periodontitis, refractory periodontitis, gingival nevi, pre-prosthodontic and orthodontic periodontal surgery. The patients were selected based on the following criteria: (1) no existing systemic diseases such as diabetes\(^\text{29}\) or hemorrhagic disorder that could affect the treatment outcome, (2) no history of antibiotic therapy one month prior to the surgical procedures, and (3) teeth directly related to the surgical site should be vital and their periodontal conditions were, if possible stabilized with conventional scaling, root planing, and prophylaxis. Consent for periodontal and especially laser treatment was obtained. Provisions of the Helsinki Declaration of 1975, ethical principles in medical research involving human subjects, as revised in 2000, were observed throughout this study. Surgical interventions, such as surgical curettage, gingivectomy, gingivoplasia, osteoectomy, and osteoplasty, were considered only in cases of acute periodontitis or when the periodontal inflammation failed to improve in three months after conventional mechanical debridement.

Documentation, such as clinical attachment levels, tooth vitality tests, intraoral photographs, and panoramic and periapical radiographs, were collected before the laser treatment. The surgical sites were locally infiltrated with Xylocaine (lidocaine HCl, with 1:100,000 epinephrine (Dentsply Canada Ltd., Woodbridge, Ontario, Canada), and no nerve block was used. All of the laser surgical procedures were performed with Er:YAG (2940-nm) lasers (DELight\(^\text{TM}\) and VersaWave\(^\text{®}\), HOYA ConBio, Fremont, Calif.), and strict laser safety requirements in the operatories were observed.\(^\text{19-20}\) The surgical sites were irradiated with multiple laser pulses, with individual pulse energies varying between 30 and 120 mJ, pulse repetition rates between 10 and 30 Hz, and pulse duration of approximately 250-300 \(\mu\)s. The laser beam was delivered through an optical fiber connected to a round-exit contact tip 600 \(\mu\)m in diameter. The exit power at the contact tip was monitored by a power meter (PowerMax 600\(^\text{™}\), Moleotron Detector, Inc., Portland, Ore.) before each procedure. This contact tip was kept in near or direct contact with the target tissues, with variations of spot diameters between 0.6 and 1 mm. Power densities of 162 to 12 W/cm\(^2\), based on the 600-\(\mu\)m contact tip and power output measured by the power meter, were applied; higher density was used for tissue ablation and lower setting for bacterial reduction and tissue coagulation. The surgical site was irrigated throughout the laser procedures with filtered water emitted from the contact tip itself and from an external air-and-water syringe. At the completion of the surgical procedure, hemostatic cotton pellets (Racellet #3, Pascal Co., Inc., Bellevue, Wash.) and/or 4-O...
silk sutures were used as necessary. The patients were instructed to follow the postsurgical care protocol, and no prescriptions for analgesics or antibiotics were prescribed. No special mouthwash was given, and regular home care except at the surgical site was suggested. All of the patients were contacted the next day for postsurgical assessment. Regular home care resumed after the surgical sites were re-examined, and the sutures were removed at the one-week recall appointments. All of the clinical observations, along with the patients’ assessments, were collected one week, one month, three months, and up to four years later. It is important to note that this study made no attempt to gather statistics that would be analyzed for probability significance; rather it attempted to show that the use of the laser was beneficial in the treatment of the patients’ periodontal disease.

RESULTS
A total of 67 vital teeth were directly treated with a combination of 104 individual surgical procedures for this group of patients. The most common procedures were surgical curettage (n = 52), followed by gingivectomy (n = 47). The most common surgical site was the posterior maxilla (n = 29), followed by the posterior mandible (n = 24). The most common indication for laser periodontal surgery (24 out of 60 procedures) was moderate-to-severe acute periodontitis. The average amount of local anesthetic used was 0.5 ml; only local infiltration was used and no nerve block was required. Despite the extensive nature of some of these procedures, there were only two cases in which conventional full periosteal flaps were raised; sutures were required for these two cases, as well as for five other surgical sites. The blood clotting process was enhanced through the use of the hemostatic cotton pellets in 16 sites. There was no report of air emphysema at any of the surgical sites. After the laser treatments, one of the patients was prescribed a course of antibiotics as a precaution due to the severity of the initial infection, and because the surgical site was very close to the maxillary sinus; otherwise no medication was prescribed for the other patients. They were contacted the next day and no bleeding or swelling was reported. One of the patients took an over-the-counter analgesic, and another complained of soreness but did not require any medication; mild soreness to no discomfort were reported by the rest of the group. One patient did complain of sensitivity to temperature which required one week for the symptoms to be resolved. Follow-up periods ranged from 6 to 54 months, with an average mean follow-up period of 2.4 years. The probing depths were normal, and there were signs of clinical attachment improvements. All of the treated teeth remained vital and functional during the follow-up period.

CLINICAL CASES
Patient #1
The patient was a 63-year-old female recovering from breast cancer treatment. Although her medical history was not ideal, she was selected because her last chemotherapy treatment had been more than three months prior, and her periodontal health was excellent. For this patient to have a more balanced gingival appearance, crown lengthening was required (Figure 1). After the surgical area...
was anesthetized and the new parabolic level was initially designed with superficial lasing (Figure 2), the excess gingival tissues were removed with the Er:YAG laser. To achieve normal biological width at the new gingival level, the underlying dental alveolar bone was reduced (Figure 3). Laser gingivoplasty, or festooning, was used to bevel the surface geometry of the new attached gingiva (Figure 4), and the final impression was taken after the abutment was prepared.

The subsequent healing was uneventful, mild sensitivity was reported, but she did not require any medication. The gingival margin was stable and healthy enough for the final insertion in 2 weeks (Figure 5). The surgical results remained stable, and the central incisor was asymptomatic 6 months later (Figure 6).

Because gingiva and bone are composed of varying densities of fibrous connective tissues, extracellular components, and high water content (approximately 70% for gingiva and 10 to 20% for bone), through selective laser energy absorption and by keeping the contact tip either angled away from the root and bone surfaces for the selective gingivectomy or along the edges of the alveolar bone for marginal osteoectomy, both the soft and hard tissues were ablated and modified with the same laser. With proper water irrigation, there was no surface carbonization, smoke formation, or tissue shrinkage. The treatment outcome of this procedure was relatively predictable, and hemostasis was stable enough that the final impression was taken at the end of the surgical procedure. There was a safety concern when this hard tissue laser was employed in such close proximity to the root surface and the alveolar bone. As demonstrated, if the intention and the direction of the energy application are carefully planned ahead, this laser may be used safely for selective ablations, even in such a confined surgical site. In spite of the initial concern over her possible weakened immune response and healing capacity for which conventional treatment had been refused, as noted before, the wound healing was uneventful and took place without the assistance of medication.

Patient #2

For this patient, surgical periodontal treatment was also refused because the prognosis for his infected premolar was deemed hopeless. For this 66-year-old male patient, who was taking antihypertensive medication, it was recommended that his upper right second premolar be extracted because of acute periodontitis and severe bone loss (Figures 7 and 8). The patient’s blood pressure was stable and under control, and the rest of his dentition was functional and normal. After the buccal and lingual areas were anesthetized, a buccal mucoperiosteal flap was raised. The infected granulation tissues were removed around the root surfaces and on the raised flap...
Affinity of erbium lasers.

With water irrigation, the exposed bone surfaces were lightly irradiated in noncontact mode with the lowest power density setting. Once stable hemostasis was accomplished, the surgical wound was closed with a 4-O silk suture. Despite the initial infection and gingival swelling, no antibiotics or analgesic medications were prescribed. There was no report of any swelling or pain, and, most importantly, there was no bleeding at the day-after reassessment. The surgical area was monitored further for 1 week (Figure 10), 1 month (Figure 11), and 6 months (Figure 12). Clinically, the premolar was asymptomatic and functional in 2 months, and there were radiographic signs of bone regeneration in 6 months (Figure 13).

**Patient #3**

This patient was only 26 years old when the extraction of her periodontally weakened right lateral incisor (Figure 14) was recommended (Figure 15).

Although her overall periodontal condition improved after sessions of conventional debridement (Figure 16), this extensive periodontal pocket (Figure 17) became an urgent concern when orthodontic treatment was considered.
The surgical approach was very similar to the one taken for patient #5 in terms of controlled access, granulation tissue removal, root surface irradiation (Figure 18) and suturing (Figure 19). The recovery of her surgical site was uneventful 1 week later (Figure 20) and remained asymptomatic throughout her ensuing orthodontic treatment.

Two-and-a-half years later, both the periodontal probing (Figure 21) and radiograph (Figure 22) show quite satisfactory clinical reattachment (Figure 21) and bone remodeling around the initially “hopeless” incisor.

**Patient #4**

This patient was a healthy 58-year-old male who presented with an infected periodontal pocket (Figure 23). After it was probed and calibrated (Figure 24), the inflamed granulation tissues were selectively separated from the remaining healthy attached gingiva and within the periodontal pocket (Figure 25).

Although infection was initially present, no medication was prescribed and the patient reported no need for any; the surgical site recovered without any incident (Figure 26). Clinical attachment was eventually reestablished in 1 month (Figure 27) and remained stable 2 years later (Figure 28).

**DISCUSSION**

There were 23 similar clinical scenarios in the study. The patients typically presented with varying degrees of symptoms and contributing factors, which would normally require invasive conventional open-flap surgery and prescriptions for antibiotics and analgesics, followed by a long period of convalescence. With the flexibility of the Er:YAG laser contact tip, the surgical sites were carefully and precisely designed, the subsequent instrumentations were less invasive, and laser energy transfer was finely controlled. As a result, the healing experiences of these patients were much more pleasant, and the surgical outcomes were more controlled.

Although there were signs of clinical reattachments for all of the treated areas consistent with Gaspirc and Skaleric in their five-year, 25-patient study, there was no attempt to compare the quantitative assessment of the clinical attachment levels, since the gold standard for surgical reassessment of the actual bone level is not appropriate for clinical studies of this nature. Then, again, if the main objective of periodontal surgery is the establishment of a new connective tissue attachment to a root surface previously exposed to periodontal disease, the collective clinical and radiographic observations are quite supportive of the effectiveness of this new treatment modality.

With the ablation of both hard (alveolar bone) and soft tissue (granulation and gingival tissue) precisely controlled, periodontal tissue reshaping or recontouring can be planned and performed efficiently with the Er:YAG laser. The bactericidal and possible bio-stimulation effects of this radiation with no carbonization or intense coagulation allow faster wound healing without any major postoperative swelling, pain, or bleeding. By allowing the various...
growth factors involved in wound healing to work soon after the surgery, the less-than-profound hemostasis from the Er:YAG laser as compared with other intense coagulation, can be beneficial and, in many situations, preferable. While these laser surgical benefits can be helpful in certain aspects of periodontal surgery, it is important to note that the use of lasers should be considered as an addition to our present armamentarium, not as a replacement for the well-established surgical principles and techniques that have been developed since the first gingivectomy was reported.1 Because of the non-touch to light-touch requirements, the use of lasers is technique-sensitive, and due to the proximity of the irradiation to dental and bone tissues, proper training and understanding of basic laser physics is required. Appropriate laser parameters, such as power density, pulse duration, exposure time, and water irrigation, should be carefully considered. Although the laser treatments in this study have been successfully carried out, one cannot ignore an enormous contributing factor to success: the patient’s compliance with respect to his or her daily bacterial plaque control.

It is normal to expect a better treatment outcome, or at least better control of it, when we incorporate any new technology into our operatory. The object of this study was to document tissue responses to Er:YAG laser radiation use in surgical periodontal procedures. In particular, we wanted to evaluate whether it was safe and effective to operate the laser in close proximity to root and bone surfaces with less profound coagulation. In the present study, there were no reports of any postoperative hemorrhagic complications or side effects among the 60 patients, and the dental hard tissues that surrounded the target sites remained vital, functional, and asymptomatic.

The average amount of aesthetics that were reported and the way the aesthetics were used seem to suggest that the demand for aesthetics was reduced. This may be related to the more confined and superficial surgical sites, which, in turn, reduced the possibility of bacteremia and the demand for antibiotics and analgesics. This was of benefit to some of the patients in this study who had significant medical history.

CONCLUSION

This is an uncontrolled clinical study that has evolved from a private practice setting; however, the potential benefits of using an Er:YAG laser for periodontal surgery are quite evident. Based on the clinical observations collected, it is both safe and effective to use this laser wavelength in the manner described for periodontal surgery. Further investigation, ideally in the form of a randomized, controlled clinical study, will be required to validate these clinical results.

AUTHOR BIOGRAPHY

Dr. Frank Yung graduated with honors from the Faculty of Dentistry, University of Toronto, Ontario, Canada in 1980. From the Academy of Laser Dentistry he achieved his Advanced Proficiency in the use of diode (980 nm) and Er:YAG (2940 nm) lasers in 2003 and 2004, respectively, and received his Educator certificate in 2005 and the Leon Goldman Award for clinical excellence in 2007. He is also a Fellow of the American Society for Laser Medicine and Surgery. Dr. Yung may be contacted by e-mail at frankyung@rogers.com.

Disclosure: Dr. Yung lectures for the Institute for Laser Dentistry and receives honoraria as compensation.

REFERENCES


A Periodontal Health System: Diagnosis, Treatment, and Retention

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**INTRODUCTION**

The maintenance of periodontal health has long been a goal that has seemed to elude some patients. With the increased use of modern technology we now have new tools to fight this pervasive and costly problem. While caries attacks the primary dentition and ravages the teeth of our youth, periodontal disease is the most pervasive problem seen in patients after the eruption of all posterior teeth. With this in mind, the modern dental practitioner must seek out, recognize, and present treatment options for eradication or at least control of adult onset periodontal disease.

With the years of education, research, and training in periodontal therapy, both surgical and nonsurgical, clinicians need only to put together a systematic approach to the examination of each and every patient followed by treatment directed from the data collected. With the results of such a system, we will be able to help our patients keep their teeth for the rest of their lives.

The goal of this article is to present such a system that has been successfully used in this author’s practice for 15 years, and one that can be easily implemented in every office. With a combination of high-tech, low-tech, or no-tech treatment, we are now able to provide health for each and every patient that presents in our office for treatment.

**BASIC PREMISE**

The basic premise that guides periodontal treatment is that the therapy our practice provides can be successful only if our patients continue to care for themselves. The goals of our treatment are to:

1. Create an environment where active periodontal disease can heal.
2. Teach the patient an effective means of keeping the periodontal structures clinically plaque- and bacteria-free. Those home care instructions are detailed below.
3. Motivate the patient to perform the necessary cleaning steps on a continuing basis. Motivation is based on the acquisition of periodontal health, lower cost for dental treatment, and less chance of recurrence that would necessitate retreatment at shorter intervals.

Bacterial plaque left undisturbed will become calcified and the bacterial component of this plaque will attack the epithelial lining of the pocket, resulting in increased bleeding, swelling, and inflammation adjacent to the bacterial plaque. Left untreated, this inflammatory destruction will migrate apically, causing marginal and interseptal bone loss. As bone loss occurs, teeth become more susceptible to the forces placed on the teeth during both function and parafunction and become increasingly mobile, which then can accelerate continual bone loss. It is clear, then, that periodontal disease is an advancing, progressive disease that is self-perpetuating until the cycle is stopped through interceptive treatment. We are able to achieve this result through creating an environment in the mouth where the patient can effectively remove all bacterial plaque each day. If we are able to identify the very early signs of disease, correct the environmental factors that start the inflammatory processes, we will be able to intercept the disease and prevent a continued inflammatory cycle.

**INTERCEPTIVE DIAGNOSIS**

At every new or re-care visit, our patients need to be evaluated for early signs of disease using all the tools at our disposal. Using necessary radiographs, clinical dental evaluation, periodontal pocket charting, oral cancer examination, as well as an occlusal contact evaluation, we are able to identify patients that are at risk for beginning on the periodontal disease cycle.

This article’s focus is not to elaborate on radiographic, clinical, occlusal, or oral cancer examinations; however, the periodontal pocket depth probing chart is of
primary importance\(^2\) during periodontal diagnosis. Through the use of such a chart, we can identify bleeding, suppuration, mobility, as well as hard and soft tissue loss. Not only is this record an effective diagnostic tool, but it can be used as a chronologic monitor to document the advance or control of the disease process.

During the history review, we should be attentive to the patient’s statements. Comments regarding a bad taste, odor, bleeding, and loose teeth need to be reviewed and examined further in order to avoid missing clues that may lead to a definitive diagnosis.

During the soft tissue examination, a six-point pocket charting of each tooth will provide a baseline to evaluate pocket depth and help determine the most appropriate treatment for the patient. Our office uses the STM\(^a\) Probe (Pro-Dentec, Batesville, Ark.), a device operated by one person that records the pocket depth. This probe is convenient to use and it provides audible feedback, as well as a paper tape used to document the exam in the patient’s computerized chart. Since the patient can hear the charting, he or she could easily relate increased tenderness on probing with deeper pocket depths. The combination of pocket charting, audible feedback, and tissue sensitivity enables the patients to take part and share in their diagnosis as well as ultimate treatment.

Muscle palpation and visual examination accompanied by a light-based examination of the oral structures will assist in early detection and interception of oral cancer. We use a VELscope\(^a\) (LED Dental Inc., White Rock, British Columbia, Canada) to evaluate the naturally occurring variations in fluorescence to identify normal patterns in the oral mucosa as well as to pinpoint abnormal patterns. These abnormal patterns often highlight early dysplastic changes that would have been difficult or impossible to detect with the unaided eye and that need further evaluation through follow-up, biopsy, or surgery.

After data collection, results are used to:
1. determine the appropriate course of treatment
2. submit for insurance predetermination of benefits
3. follow treatment efficacy during re-care visits.

Once data collection has been achieved, the individualized treatment protocol is developed next, with definitive results in mind.

### RESULTS-BASED CLASSIFICATION

The patient is then given the specifics of the disease according to the following classifications:\(^4\)

- **Healthy**: pockets 3 mm or less and no bleeding or inflammation.
- **Type I – Gingivitis**: pockets 3 mm or less with bleeding on probing and inflammation with some debris possibly present supragingivally.
- **Type II – Mild Periodontitis**: pockets 4-6 mm with slight bone loss, bleeding on probing, inflammation and debris present subgingivally.
- **Type III – Moderate Periodontitis**: pockets 6-7 mm with bone loss, bleeding on probing, inflammation and debris present subgingivaly with some mobility and possible furcation involvement.
- **Type IV – Advanced Periodontitis**: pockets in the 7 mm or greater range with heavy bleeding on probing, inflammation and suppuration, debris present supra- and subgingivally with mobility and furcation involvement.
- **Type V – Refractory Periodontitis**: inflammation and pocket depths of 4 mm or greater in a periodontium previously treated for periodontal disease.

With these data-based classifications we are able to point out the difference between disease and health as well as direct treatment to the achievement of our goals for treatment and periodontal tissue stability.

### TREATMENT PROTOCOLS

Based on the disease classification, the therapy will consist of specific procedures.

**Healthy**

The patient receives a prophylaxis.

**Type I: Gingivitis**

The patient receives conventional scaling assisted by the use of topical anesthesia. The laser is used adjunctively to reduce the bacterial presence. A thorough prophylaxis and polishing is performed and home care instruction is given. This regimen consists of brushing and flossing instruction focused on intrasulcular brushing, and use of a rubber stimulator tip focused on massaging the labial and lingual external surfaces of the papillae as well as the marginal gingiva.

**Type II: Mild Periodontitis**

The patient is treated through the use of conventional scaling and root planing, assisted by the use of topical anesthesia, and the use of a laser. The laser will disinfect the sulcular tissues, decrease the incidence and severity of bacterial migration into the bloodstream and throughout the body, and increase the time that destructive bacteria would take to repopulate the periodontium. This is of particular benefit for patients with depressed immune systems due to chronic medical conditions.\(^5\) The pockets are then rinsed with chlorhexidine, and a thorough prophylaxis and polishing is performed. The home care regimen described above is taught and supplemented with chlorhexidine application using the rubber tip stimulator.
Type III: Moderate Periodontitis
The patient is treated very similarly to the Type II protocol above, that is: conventional scaling and root planing, assisted by the use of topical anesthesia, laser sulcular debridement and disinfection, and chlorhexidine rinses. However the author has found that this type of treatment alone may not reduce the pocket depths adequately to create a cleansable/maintainable gingival sulcus. If there are select areas not amenable to pocket reduction, the author frequently uses locally applied antibiotics to slow the pathogen repopulation of the gingival sulcus and to promote gingival adherence to the root surface. In cases where initial pocket depths exceeded 3 mm and surface. In cases where initial pocket depths exceeded 3 mm and antibiotic immediate post-treatment laser pocket depths exceeded 3 mm and antibiotic immediate post-treatment laser prefer to try the above therapy first and evaluate the results for 3 months before referral. In this way, initial therapy can be completed in a conservative manner and the patient can be referred for selective areas of treatment where needed. In the author’s experience, there is a reduced need for advanced surgery following the described treatment. An example of an exception would be a free gingival grafting procedure, which are always referred to a periodontal specialist’s office.

Type IV: Advanced Periodontitis
With advanced disease as characterized above, we first treat as a Type III, including scaling, root planing, laser therapy, and locally applied antibiotics. After the initial therapeutic regime, the patient is evaluated for residual periodontal disease at 3 months and at regular intervals thereafter. After evaluation, if pocket depths are still greater than 5-7 mm and/or mobility measurements are 2+ or more, immediate referral to a periodontist is discussed. (At the initial examination the possibility for further specialist treatment of the patient’s condition has already been discussed.) In most cases, patients prefer to try the above therapy first and evaluate the results for 3 months before referral. In this way, initial therapy can be completed in a conservative manner and the patient can be referred for selective areas of treatment where needed. In the author’s experience, there is a reduced need for advanced surgery following the described treatment. An example of an exception would be a free gingival grafting procedure, which are always referred to a periodontal specialist’s office.

Type V: Refractory Periodontitis
The patient will be treated according to the Type IV protocol, with a similar referral option, as discussed above.

A few words about laser treatment by a dental hygienist: If allowed by State Dental Practice Acts in the United States, sulcular debridement and disinfection can be performed by a registered dental hygienist, using a laser instrument with an indication for use for that procedure. We recommend that the hygienist achieve Academy of Laser Dentistry Standard Proficiency before treating patients in this manner. However, where State law does not allow hygienist treatment, the patient must be treated by the doctor who would perform laser sulcular debridement as well as any gingival reshaping needed.

CLINICAL CASE
A 69-year-old Caucasian male presented with a chief complaint of “bad breath and bleeding gums.” Medical history review revealed adult onset diabetes, high blood pressure, as well as a medically managed heart condition. The patient was currently taking a list of 8 medications prescribed to control his multiple medical conditions. A clinical dental examination revealed a Type III (Moderate Periodontitis) classification with selected areas of advanced disease. Dental treatment planning was postponed in order to focus on improving the periodontal status and bringing the oral condition into a maintainable condition. Radiographic evaluation was consistent with the clinical diagnosis, showing no abscesses or cysts present. Limited restorative dentistry was performed to remove caries and place the patient in a holding pattern to allow for periodontal treatment. The discussion below will follow the completed treatment as well as the results obtained.

The patient exhibited disease and proceeded with treatment, according to our protocol. Figures 1 and 2 show the pretreatment views of the periodontium.

The patient’s treatment consisted of scaling, root planing, laser sulcular debridement, and a locally delivered intrasulcular antibiotic, as shown in Figure 3. The medication was placed into pockets that retained depths greater than 3 mm.

Dental treatment planning was postponed in order to focus on improving the periodontal status and bringing the oral condition into a maintainable condition. Radiographic evaluation was consistent with the clinical diagnosis, showing no abscesses or cysts present. Limited restorative dentistry was performed to remove caries and place the patient in a holding pattern to allow for periodontal treatment. The discussion below will follow the completed treatment as well as the results obtained.

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weeks (Figures 5 and 6). At 6 months, the tissue appeared healthy (Figure 7). Unfortunately, the patient was not getting the results from the instructed home care regimen, and he was compromised by his diabetes and heart medications. He understood those factors could significantly jeopardize the apparent success of the therapy provided.

Laser-assisted scaling and root planing was performed in 5 separate visits at approximately 2-3 week intervals. This enabled the author to evaluate each section as it was healing and perform another area at the same visit. The laser technology used in the maxillary arch was a 1064-nm Nd:YAG laser (dLase 300, American Dental Laser, Birmingham, Mich.) with 2.50 Watts at 25 Hz and a 320-micron bare fiber. A 980-nm diode laser
Levy

(Compass 980°, OroScience, Inc., Palo Alto, Calif.) at 1.2-1.5 Watts continuous wave with a 300-micron bare fiber was also used for this patient in some areas of periodontal treatment. No significant difference in results was seen between the two laser wavelengths. Anesthesia was used in most cases in compliance with the patient’s desires.

Ten months after the initial charting, and after Type III therapy without any soft tissue surgery, the probing chart (Figures 8a and 8b) showed significant pocket depth reduction. Figure 8a shows initial and 10-month depths by comparison.

Two 10-month postoperative photographs illustrate the periodontal health improvement. Figure 9 shows the lingual maxillary tissue, which, compared to Figure 2, has better color and tone; and Figure 10 shows a 2-mm pocket depth reduction on tooth #9 with no bleeding. Pocket resolution, although not ideal, was evident in spite of the compromised medical history and less-than-ideal home care compliance. It is necessary for us to recognize that control of the disease process is a very elusive concept in periodontal therapy and this technique, with its systematic approach, has given this patient a good chance of improving the periodontal prognosis.

**CONCLUSION**

A systematized approach to examination, diagnosis, categorization, and treatment has been presented. If this approach is followed on every patient, clinicians may be able to greatly reduce the incidence as well as the severity of periodontal disease. Once diagnosed and treated, the patient will still bear the major share of responsibility for continued maintenance. As has been stated previously, our patients’ care is mostly in their hands. We cannot do what a patient will undo with a lack of follow-through care.

Figure 9: View of maxillary anterior lingual

Figure 10: Periodontal probe in place in pocket whose depth has been successfully reduced

Figure 8b: Detailed, full-mouth, 10-month pocket depths are shown in the upper part of this figure. Note the statistics on the lower portion of the illustration show periodontal improvement

Figure 8a: View of maxillary anterior lingual
Our goals must continue to be education, guidance, and as little clinical intervention as necessary.

**AUTHOR BIOGRAPHY**

Dr. Arthur Levy is a 1971 graduate of Fairleigh S. Dickinson University School of Dental Medicine and continued his education in a General Practice Residency in the Newark Beth Israel Medical Center in Newark, New Jersey. He spent two years at the Malcolm Grow Medical Center in Washington, DC as a Prosthodontic Officer in the United States Air Force. Dr. Levy was an Associate Clinical Instructor at Fairleigh S. Dickinson University School of Dental Medicine from September 1976 through May 1989, and has published and lectured worldwide on many topics including lasers in dentistry. He currently maintains a private practice in Chester, New Jersey, where he practices laser-assisted Restorative and Cosmetic Dentistry. Dr. Levy is a charter member of the ALD and holds Advanced Proficiency in Nd:YAG as well as a Master of the Academy of Laser Dentistry certificate. He has been active in numerous ALD committees including serving as Chair of the International Relations Committee for several years. He previously served on the ALD Board of Directors at various times in the preceding 15 years. In 2007 Dr. Levy earned the ALD Distinguished Service Award. He is married to his wife of 28 years, Mitzi, and has 5 children and 7 grandsons. Dr. Levy may be contacted by e-mail at chesterdental@embarqmail.com.

**Disclosure:** Dr. Levy is currently a lecturer for LED Dental, for which he receives an honorarium. He is also a stockholder in Lantis Laser. He was a clinical advisor for OroScience, and had received one of the company’s diode lasers for evaluation.

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Laser-Tissue Interaction I

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INTRODUCTION

Laser-tissue interaction is the use of light energy that is absorbed by the tissue to produce a photobiological effect. Such effects can be manifested as photodisruption, plasma induced-induced ablation, photoablation, thermal, and photochemical. The type of photobiological effect is largely a function of the power density and pulse duration. The highest power densities and shortest pulse durations produce photomechanical effects, and the lowest power densities in conjunction with the longest pulse durations (continuous wave) produce photobiological effects.

As can be seen in Figure 1, power densities in the millions of Watts per square centimeter produce photodisruptive effects. These effects are characterized by shock waves, optical breakdown, and disruption of molecular bonds but have no clinical applicability with the currently available dental lasers.

As the power density decreases and pulse length increase, the next interactions are photothermal effects, which include pathogen deactivation, coagulation, vaporization, and carbonization. Many nonsporulating bacteria are readily inactivated at approximately 50°C, coagulation occurs at approximately 60°C, vaporization at 100°C, and carbonization > 200°C. These are the predominant effects concerning most dental practitioners who use lasers. To be clear, however, surgical procedures on dental hard tissue, that is, tooth structure and bone, are most affected by both vaporization and
carbonization; dental soft tissue interacts at all of the above temperatures.

At the lowest power densities and longest pulses, including continuous wave, the photochemical and biostimulatory effects are found. The photochemical effects include: composite curing, which is well known to the dental profession; photodynamic therapy, a modality in which a spectrally adapted chromophore is injected or applied as a photosensitizer and irradiated with an appropriate wavelength of light, causing the desired reaction to occur only in the irradiated area; and laser-induced fluorescence, a technique where one wavelength of laser energy is absorbed and is emitted at a slightly longer wavelength, thus enabling a receptor to assess tissue changes. This fluorescence can be used for carious lesion detection as well as mucosal cancer screening.

The photobiomodulation effects are accomplished with low energy levels and low thermal input and include, but are not limited to, biostimulation, pain relief, wound healing, and collagen growth. Photobiomodulation effects deserve an entire separate article and will be given only a cursory mention here.

PHOTOTHERMAL INTERACTION
The primary laser-tissue interaction for dentistry is a photothermal one. Several key definitions must be understood prior to studying the thermal interaction principles. One is that of vaporization, the conversion of water to steam in order to facilitate tissue removal. Since water turns to a gas at a much lower temperature than other cellular elements, vaporizing it becomes a desirable end point in removing tissue.

A second important definition is of ablation, which is the removal of a segment of tissue by a thermal interaction. The ablation crater is simply the area in which tissue removal was accomplished by rapid heating of the interstitial and intracellular water to 100°C, causing vaporization. The laser impact on soft tissue produces a configuration as shown in Figure 2, which depicts different zones of thermal effect. A similarly shaped ablation crater is produced when the erbium family of lasers vaporizes dental hard tissue. During soft tissue surgical procedures, a residue of this process, called coagulum, can adhere to the laser fiber or tip. This debris should be regularly removed since it can interfere with visualization of the procedure.

Another significant term is coagulation, the heating of the layer of soft tissue that is proximal to the area of vaporization to denature protein and control bleeding. Coagulation occurs when the soft tissue is heated to 60°C and is caused in part by the initial laser strike’s subsequent penetration of the photons which were not absorbed in the ablation crater. It is also a by-product of the conduction of the residual heat of vaporization to the underlying tissues. As will be discussed later, this conduction is directly proportional to the time the laser energy is applied. This thermal result is either good or bad depending on the application and amount of coagulation present. With too little coagulation, bleeding and gingival seepage could compromise visibility of the surgical field; but too much coagulation can delay healing and cause postoperative discomfort. In procedures where immediate vascularization is desired, e.g., free gingival grafts, coagulation in any amount can be deleterious. Ideally, the remaining tissue should be pink, not toasted or carbonized (charred).

Lastly, the laser clinician should understand carbonization, which is the heating of tissue remnants beyond vaporization temperatures causing a char layer to form which can be accompanied by an acute temperature increase in the surrounding tissue, due to the absorption characteristics of carbon. Carbonization can occur in both hard and soft tissue.
Swick

Figure 3 shows an example of a laser incision, performed with an 810-nm diode laser. The author used these parameters to produce the resultant pink tissue: 30 Watts peak power, 530 Hz, 100-µs pulse width at 1.58 Watts average power. Figure 4 shows a laser gingivectomy with parameters popularly employed. A 980-nm diode laser was used at 2 Watts continuous wave with a 400-µm fiber. The clinical view shows that when cutting substantial amounts of connective tissue at low powers in continuous wave mode, the operator will frequently encounter what the author has termed as the “crème brûlée” effect. It is characterized by desiccated connective tissue which is hard and scratchy like the top of a crème brûlée. Figure 5 shows a histologic section of tissue from a similar procedure and settings.

Figure 6 shows gingival contouring performed with a CO2 laser at 8 Watts, continuous wave emission. The result is a carbonized surface, which some clinicians refer to as a “laser bandage,” and use as an alternative to periodontal dressing. While both Figures 4 and 6 depict tissue that is carbonized, the techniques and laser wavelengths were properly used. However, the author’s preference for soft tissue surgery is to utilize higher powers, a shorter pulse duration, and water for cooling.

With knowledge of the photothermal effects, the clinician must have an understanding how these effects are transferred. There are three mechanisms of thermal transfer: conduction, convection, and radiation. Two distinctly different laser techniques have been developed based on the type of thermal transfer that is utilized: noncontact and contact. For soft tissue procedures, radiant energy from the erbium and carbon dioxide laser wavelengths is used in a noncontact manner because of their high absorbance by water. Due to much lower tissue absorption of the near-infrared wavelengths like diode and Nd:YAG, radiant as well as conductive energy is employed. This necessitates a contact technique with some heat being derived from the fiber, sometimes called the hot tip effect. Some clinicians advocate depositing a small amount of carbon on the fiber tip to augment this hot tip effect and enhance vaporization. This technique is known as activation or initiation and can be performed by activating the laser and touching the tip on a piece of articulating paper, for example. For the best thermal precision and to limit heating of lateral tissue, the amount of heat contributed by the fiber itself should be kept to a minimum.

Conduction is the transfer of heat by direct molecular collision. According to Absten, “An area where conduction heating can become a problem is when laser is left in contact with tissue for excessive periods of time because of low (power density) applications. Unwanted heat conducts from the target tissue into adjacent tissues and may cause excessive thermal injury by heat conduction … Adequate power (power density) minimizes this thermal conduction by allowing vaporization to proceed immediately. The excess heat is carried away in the laser plume to prevent conduction. Since adequate power densities generally involve quicker vaporization times, the time allowed for conduction also decreases.” This has direct implication for the use of adequate power and the correct exposure time to achieve the most beneficial photothermal effect possible during a laser dental procedure.

Convection is the second mecha-
nism of thermal transfer.

Convection involves the heating of comparatively large amounts of gases or liquids in relation to the target tissue. The value of convection in laser therapy is the removal of the excess heat of vaporization from the target tissue. As noted above, the laser plume can serve as a method of removing heat; thus the clinician should be careful when submerging a tip or fiber into soft tissue so that the plume can escape. The convective properties of water are extremely effective in removing the excess heat of vaporization away from the hard tissue preparation or surgical site.14

Similar to the precaution for soft tissue, the clinician should remove hard tissue in a manner that avoids deep cratering so that the water can freely flow around the surgical site and the plume can escape. With near-infrared contact laser techniques, where some conductive energy is used, the author reported the High Fluence (Swick) Technique for the 980-nm diode laser in 2000 which uses higher fluences during soft tissue surgery and water for cooling.15–16 A histological study showed that water for cooling merited further investigation.17

Radiation is the third mechanism of thermal transfer. It is the transfer of energy by electromagnetic waves and is utilized in all noncontact laser modalities and to varying degrees in contact laser techniques. Radiant transfer has no heat inherent in the beam itself. Heat is created only when the target tissue absorbs the transmitted radiation and converts it to heat. As mentioned above, erbium and carbon dioxide laser modalities utilize radiant energy only in a noncontact technique, and the near-infrared laser wavelengths necessitate the use of some amount of conductive energy (contact/hot tip effect) in conjunction with radiant energy to facilitate vaporization.

Laser energy propagation in tissue

Laser energy is emitted at a very specific wavelength. Wavelength is defined as the distance of a wave between two corresponding points, and each wavelength has a unique effect on the various components of the target tissue. Consideration must be given to what occurs from the moment the laser beam strikes the tissue until it dissipates.

Optical energy is propagated in tissue by five different means: reflection, refraction, absorption, transmission, and scattering. Reflection is defined as the returning of electromagnetic radiation by surfaces upon which it is incident.18 Light is reflected at the interface between air and the target tissue, and the law of reflection states that the reflected angle equals the incident angle.18 This law applies to specular reflection which is created from a smooth polished surface, one on which the irregularities are smaller than the incident wavelength. Diffuse reflection emanates from a rough surface, or one on which the irregularities are comparable to or larger than the incident beam and does not necessarily follow the law of reflection.19 Clinically, a gold crown could produce specular reflection from a laser beam; but most of the reflected laser energy from dental tissue is diffuse. Either type of reflection can be reduced by keeping the laser beam at a 90° angle to the target tissue; however, appropriate safety glasses are required during laser procedures to protect against any reflection. [The reader is directed to “Laser Safety in Dentistry: A Position Paper” in this issue (pages 39–49) for more information.]

Refraction occurs when the direction of the light changes due to a speed change at the reflecting surface because of different refractive indices of the substances the light passes through.20 This change in beam direction could have significance when laser irradiation is reflected from an implant surface and strikes nontarget tissue, for example. This refraction can be
reduced also by keeping the laser beam at a 90° angle to the incident surface.

Absorption is the primary desired laser-tissue interaction. Absorption requires a chromophore, an absorber of light.\textsuperscript{19} Chromophores have an affinity to certain wavelengths of light, and that attraction absorbs the energy, converting a portion of it into heat. In order to maximize the thermal reaction, there should be a close match between the laser wavelength and the chromophore(s) present in the target tissue. The primary chromophores for intraoral soft tissue ablation are hemoglobin, water, and melanin,\textsuperscript{19,20} while dental hard tissue has water and hydroxyapatite as chromophores.\textsuperscript{19} A general absorption curve for commonly used dental laser wavelengths is shown in Figure 7.

Blood is comprised of 87% water, leaving 13% as other blood materials: red blood cells, white blood cells, and platelets. Red blood cells comprise about 45% of that material. Hemoglobin and oxyhemoglobin account for nearly all of the red blood cells’ volume and are present in tissues at varying percentages that are influenced by tissue type and the degree of inflammation present in the tissue.\textsuperscript{22}

The body is composed of approximately 60% water by weight\textsuperscript{23} although various tissues can contain more or less. Generally, as shown in the Figure 7, the longer wavelengths have a much higher affinity for water than do the visible and near-infrared ones. However, there is some significant variation in pure water absorption among the available near-infrared dental lasers, whose wavelengths range from approximately 800 to 1064 nm. Gutknecht offers absorption coefficient data showing 810 nm (0.12 cm\textsuperscript{-1}), 980 nm (0.68 cm\textsuperscript{-1}), and 1064 nm (0.26 cm\textsuperscript{-1}).\textsuperscript{24} However, all of these figures are several thousand times less than that of the erbium (2780 nm, 2940 nm) or carbon dioxide (10,600 nm) laser wavelengths as shown in Figure 7.

One consideration about the absorption differences is that the corresponding penetration of a wavelength in water will be the inverse of the absorption. In other words, erbium laser energy penetrates only a few microns into pure water, whereas the near-infrared laser wavelengths mentioned above can penetrate several millimeters, although the 980-nm wavelength has approximately 50% less penetration than other infrared lasers. Figure 8 offers a compilation of water absorption and penetration depth, interpreted from data from several sources.\textsuperscript{25-31} It should be noted that the graphic depicts absorption in pure water; however, the presence of pigmentation varies greatly between and within individuals. Intraoral tissues such as gingiva, buccal mucosa, hard palate, and...
Density delivered to the target area
- Power, both peak power and average power, as well as total energy
- Duration of exposure
- Amount and type of cooling of the target tissue
- Other clinician-controllable factors such as working distance and type of handpiece tip
- Other nonlaser factors that increase operational efficiency.

As was noted earlier, these aspects will be discussed in a subsequent manuscript.

**SUMMARY**
Laser-tissue interaction is multifaceted, and is based on the fundamental physical characteristics of laser energy, the composition of the target tissue, and the laser operating parameters. In dentistry, the primary interaction is a thermal one – the tissue temperature is increased to achieve a variety of results. The laser clinician should have a good understanding of these aspects before patient treatment is initiated.

**AUTHOR BIOGRAPHY**
Dr. Michael Swick is a general dentist and has offices in Allison Park and Conneaut Lake, Pennsylvania. He practices micro-dentistry, employing air abrasion and laser, working through a surgical operating microscope. He holds an Advanced laser Proficiency in the 980-nm and 2940-nm wavelengths, and Standard Proficiency in CO2, Nd:YAG, 810-nm diode, 980-nm diode, Er,Cr:YSGG, and Er:YAG wavelengths through the Academy of Laser Dentistry. He is also an Academy of Laser Dentistry certified educator as well as a Recognized Course Provider whose Standard Proficiency courses are accepted for Standard Proficiency Certification through the Academy of Laser Dentistry. He is serving on the Board of Directors of the Academy of Laser Dentistry, and is a former chairman of the Education Committee. He also serves on the Science and Research Committee, and has served on the Scientific Sessions and Nominations Committees. Additionally, he holds certification from St. Luke’s Medical Center in the Pinero Pre-cardiac Surgery Protocol with lasers. Dr. Swick is a former Fellow in the American Society for Laser Medicine and Surgery, where he has presented clinical papers. He has presented more than 300 continuing education and hands-on courses on dental lasers, both nationally and internationally. In addition, he has presented clinical and scientific papers for the Academy of Laser Dentistry, European Society for Oral Laser Applications (ESOLA)/Deutsche Gesellschaft für Laserzahnheilkunde (DGL), International Society for Lasers in Dentistry (ISLD), and SPIE. Dr. Swick may be contacted by e-mail at hitekdmdr@aol.com.

**Disclosure:** Dr. Swick has lectured, provided training, and consulted for the BioLitec, HOYA ConBio, Sirona, Kavo, and Elexxion laser companies as well as LED Dental on the VELScape and the Institute for Laser Dentistry in Canada for whom he has lectured extensively on a per diem basis. He currently is a consultant, lecturer, and trainer for the Elexxion laser company and he receives a per diem for his efforts.

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Er,Cr:YSGG Laser Use for Soft Tissue Management During the Restoration of an Implant: A Case Report

Shawn Adibi, DDS, Houston, Texas

**INTRODUCTION**

Despite some controversy about the limitations in the applications of lasers in clinical dentistry, there are many manufacturers of various types and wavelengths on the market available today. This article presents a clinical case that features an erbium, chromium:yttrium, scandium, gallium, garnet (Er,Cr:YSGG) laser that is used in the process of restoring an implant. A major advantage of a laser over electro-surgery is that the laser minimizes collateral trauma to adjacent tissues, and an electrosurgery unit must be used with great caution in the proximity of an implant. With the use of scalpel and trephine cutting-type of instruments, the main drawback is the lack of adequate control of bleeding. Various articles confirm the utility of a laser for soft tissue surgery, and particularly for soft tissue uncovering of implant bodies. Moreover, an Er,Cr:YSGG laser has shown successful clinical results for soft tissue management.

**CASE REPORT**

A 46-year old Caucasian female presented with a failed restoration of the lower right second molar, which had been previously treated with root canal therapy and presented with periapical periodontal involvement and class II mobility. The preoperative panoramic film is shown in Figure 1.

After complete review of her dental and health history, several options were presented, including a removable restoration to replace the involved tooth. However, the patient preferred replacement of the tooth using a single implant. After obtaining verbal and written consent for extraction of tooth #31 and surgical placement of an endosseous implant, 3.6 ml of lidocaine with 1:100,000 epinephrine was administered, and the tooth was removed atraumatically.

Immediately after extraction, a series of chlorhexidine rinses and curettage of the extraction site were carefully accomplished to prepare the surgical site. A 5 x 10 mm root-form, one-piece implant (OCO Biomedical Inc., Albuquerque N.M.), was tapped into the socket of tooth #31, after osteotomy. After placement of the implant in the desired location and trajectory, a synthetic absorbable bone graft (Impladent Ltd., Holliswood, N.Y.) was placed to augment and fill in defective walls around the tapered implant. Then a continuous suturing technique using a 4-0 plain gut absorbable suture (Henry Schein, Inc., Palatine, Ill.) was used to close the surgical site.

**SYNOPSIS**

This article reviews the modes of action and clinical application of novel caries detection methods including digital imaging fiber-optic transillumination, laser fluorescence, quantitative light-induced laser fluorescence, and alternating current impedance spectroscopy.

**ABSTRACT**

Since the development of the ruby laser by Maiman in 1960, there has been great interest among dental practitioners, scientists, and patients to use this technology to make dental treatment more pleasant, and oral soft tissue uses are becoming more common in dental offices. Safe use of lasers also must be the underlying goal of proposed or future laser therapy. With the availability and future development of different laser wavelengths and methods of pulsing the laser energy, much interest is developing in this growing field. This article discusses one of the newer and more useful roles of dental lasers for soft tissue management around implant fixtures. The author believes that laser applications such as the one demonstrated will facilitate increasing use of this technology.
The patient was given a removable partial denture as a temporary restoration. The partial was designed and adjusted to protect the implant during the healing and integration period. Four months postoperatively, clinical examination and radiograph revealed osseointegration of the implant with mandibular bone radiographically evident in the surgical site (Figure 2). Since the partial fit passively around the implant (Figure 3), the gingiva had proliferated around the neck of the implant, which the author had expected and planned to remove prior to the impression procedure.

An Er,Cr:YSGG laser (Waterlase, Biolase Technology, Santa Clemente, Calif.), operating at 2780 nm, was used to remove unwanted gingival overgrowth using 1 Watt at 30 pulses per second with a 15:20 air-to-water ratio in the soft tissue mode (Figure 4). High-speed vacuum evacuation was used throughout the procedure when laser emission was on. The patient, assistants, and dentist were protected with eyewear to block the specific laser wavelength at all times during this procedure. The gingival reshaping around the implant abutment was accomplished by using only topical anesthetic (TAC, Professional Arts Pharmacy, Lafayette, La.). It took approximately 60 seconds of irradiation to complete the gingivectomy to desired shape and form. In the author’s experience the procedure was completed more rapidly and with less discomfort than traditional cord retractions, and Figure 5 shows that good hemostasis was obtained.

The patient was very cooperative and comfortable during the procedure. In the author’s opinion, the ability to create accurate interocclusal bite registrations and impressions for fabrication of the restoration was much easier without the patient having anesthesia. Two weeks post impression, an aesthetic porcelain-fused-to-metal crown #31 was delivered (Figure 6).

CONCLUSION
In the author’s opinion, the laser-assisted procedure presented above is an example of improvement in pain control management, improved bleeding control, and an efficiently completed procedure relative to other modalities that the author has used. In this case, the laser produced simple preparation of soft tissues surrounding the implant abutment which facilitated making excellent impressions for the final restoration.

AUTHOR BIOGRAPHY
Dr. Shawn Adibi is an assistant clinical professor in the Department of Diagnostic Sciences and the Department of Restorative Dentistry and Biomaterials at the University of Texas Health Science Center at Houston, Dental Branch. In addition to his teaching responsibilities, he also presents continuing education courses at the University and was a co-author of a recently published article about laser fibroma removal in the journal General Dentistry. He holds Fellowship in the Dental Organization for Conscious Sedation, Associate Fellowship and Certification from the World Clinical Laser Institute, and certification of completion from the University of Kentucky for Advanced and Comprehensive Program on Temporomandibular Disorders and Orofacial Pain. Dr. Adibi may be contacted by e-mail at Shawn.Adibi@uth.tmc.edu.

Disclosure: Dr. Adibi has no conflicts of interest to disclose.
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The Removal of Porcelain Veneers Using an Er:YAG Laser: A Report of Two Cases

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INTRODUCTION
The Er:YAG laser, operating at 2940 nm, is highly absorbed in water and has indications for use on dental hard tissues. During restorative procedures, this laser can remove most existing composite resin materials. The author has used this laser wavelength to facilitate the removal of existing porcelain veneer restorations. In so doing, the treatment objectives include preserving the underlying tooth structure, possibly keeping the porcelain veneer intact, and providing a conservative mechanism for removal of the resin cement.

CLINICAL CASES
The first case involved treatment of a 48-year-old black female whose previous veneers exhibited discoloration, marginal breakdown, and an unaesthetic appearance (Figure 1). The patient was willing to have either veneers or full-coverage porcelain crowns for the enhancement of her smile. Her medical history was unremarkable.

An Er:YAG laser (DELight™, HOYA ConBio, Fremont, Calif.) was used to perform the procedure with settings of 30 Hz and 180 mJ (5.4 Watts). A 600-micron, 30-degree tip was aimed slightly defocused from the center of the target area and moved in a constant up-and-down motion for 2 minutes. The technique resulted in the complete dislodging of the veneer, fully intact. Based on the condition of the underlying tooth structure, the patient chose to have full-coverage porcelain crowns, shown in Figure 2.

The second case involved a 49-year-old black female whose medical history was unremarkable. Two weeks previously, veneers were placed on her lower anterior teeth by another practitioner to close diastemas. The patient was unhappy with the results and wished the veneers to be redone (Figure 3).

The case presented several challenges. There was difficulty gauging the distance between the teeth prior to the veneers being removed, the gingival topography was uneven and asymmetrical, and the mesial-distal to incisal-gingival ratio gave the appearance of short clinical crowns. All of these factors were explained to the patient prior to the veneer removal to make her aware of these obstacles to achieving a satisfactory result.

The first step was to perform crown lengthening to create additional clinical crown height. The
gingival modification was performed with an 810-nm diode laser (DioDent™, HOYA ConBio), 1 Watt continuous wave with a 400-micron quartz fiber in contact mode. The procedure lasted 11 minutes, and the immediate postoperative view is shown in Figure 4. Subsequent to the above crown lengthening, the Er:YAG laser was used with the identical settings of the first case to remove the veneers. Figure 5 shows the laser handpiece held perpendicular to the labial surface of the veneer, and the laser energy is activated and directed through the porcelain veneer. In this instance, the veneers did not remain intact, but broke into fragments as they separated from the underlying tooth structure. It took approximately 11 minutes to remove the veneers and cement from the teeth with the laser.

The new veneer preparations were refined (Figure 6) and impressions were taken for 6 new restorations. The new porcelain veneers were tried in for fit verification and patient approval. They were inserted using clear shade cement (Nexus, Kerr Corporation, Orange, Calif.), and the final postoperative view is shown in Figure 7.

**DISCUSSION**

The basis for the clinical effectiveness of this procedure lies in the assumption that the laser energy is transmitted through the veneer and absorbed by the resin-based luting cement. The relatively high Er:YAG laser power (5.4 W), the relative thinness of the porcelain veneer, and its partial translucency lead to a plausible explanation of the mechanism of action. However, the reader is reminded that the power setting used could remove additional tooth structure after the cement is ablated. Thus the practitioner should carefully observe the process.

In comparing the two cases, questions arise as to why the veneers separated from the teeth differently. There are two possible explanations. In Case I, the laser energy may not have been absorbed by the porcelain but traveled through to ablate the underlying cement. This would have allowed the veneer not to be damaged as it released from the tooth. In Case II, the veneer material may have had some entrapped water which absorbed the energy of the Er:YAG laser, causing the disruption of the integrity of the structure. The author thus theorizes that the composition of the two veneers may have been different.

In conclusion, it is the author’s opinion that the Er:YAG laser could be used as a viable alternative for the removal of porcelain laminate veneers. In some instances the author has been able to remove the veneers whole, intact, and efficiently. Also, use of the laser might aid in the conservation of underlying tooth structure when compared to a high-speed handpiece.

**AUTHOR BIOGRAPHY**

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**Disclosure:** Dr. Wyatt lectures for LED Dental and receives compensation.
Laser Safety in Dentistry: A Position Paper

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John G. Sulewski, MA; Joel M. White, DDS, MS

SUMMARY
Laser use in general dental practice has grown considerably over the past 20 years, both in numbers and scope of use. The registered laser owner is responsible for ensuring that all personnel have a thorough knowledge of laser safety. There exists a duty of care to all dental health care professionals in the application of lasers in clinical practice. Such regulations may exist through federal and/or international standards. The duty of care extends to all staff as well as patients.

General and specific measures must be employed to ensure the

GLOSSARY
ANSI: American National Standards Institute. A not-for-profit organization, founded in 1918, that oversees the administration and coordination of the United States private sector voluntary standardization system.


FDA: The U.S. Food and Drug Administration, a division of the U.S. Department of Health and Human Services. Founded through consolidation in 1930. The FDA enacts the provisions of the Federal Food, Drug and Cosmetic Act (rev. 2004). The FDA Center for Devices and Radiological Health (CDRH) is responsible for the premarket approval of all medical devices, as well as overseeing the manufacturing, performance and safety of these devices.

IEC: International Electrotechnical Commission. Founded in 1906, the IEC is a not-for-profit, nongovernmental international organization that prepares and publishes international standards for all electrical, electronic, and related technologies. The headquarters are in Geneva, Switzerland.

ABSTRACT
In oral health care, the number and range of laser-based technologies have expanded enormously over the past two decades. The scope of this paper is to alert the dental professional to the extent, application, and responsibilities associated with safety when using lasers designed for use in dentistry. By far, the majority of laser instruments are within the private (nonhospital) clinic setting. Laser use extends from those procedures of a diagnostic or nonsurgical (biostimulatory or photochemical) nature, to more powerful devices that are used in surgical procedures. Low-powered lasers may deliver energy of a few millijoules, whereas surgical lasers may have pulsed emission modes capable of peak power delivery in excess of 1,000 Watts. Laser radiation can be dangerous, because it is concentrated and powerful.


In addition, interpretation of these standards complements the core of knowledge outlined in the Curriculum Guidelines and Standards for Dental Laser Education that is required by the certification examinations of the Academy of Laser Dentistry.
safe use of lasers in dentistry.

Laser safety is applicable according to the class of laser being used.

**INTRODUCTION**

There is a basic requirement of the clinician and associated staff to ensure that laser use is carried out within a safe environment. Key to this requirement is an understanding of the device being used, laser physics, and adherence to federal, national, and international statutes. These regulations may apply either specifically to laser use or within broader health and safety legislation.

Laser safety considerations are proportional to established and recognized risk. The potential maximum power output will define a basic approach, but specific to more powerful lasers are measures taken to address additional risks of laser damage to nontarget oral tissue, skin, and eyes. Such damage may be the result of direct exposure to the laser beam or through the combustion of chemicals, gases, and materials used in dentistry.

The protection of those personnel involved in laser treatment – patient and staff – is a prime consideration, but it is also important to consider those measures required to safeguard against any risk events.

History can provide us with records of injuries occurring to people due to lasers. The U.S. military, FDA, U.S. Department of Energy, U.K. Medicines and Healthcare Regulatory Agency, and Rockwell Laser Industries, to name a few, maintain logs of laser-related incidents through their device-reporting mechanisms. The following anecdotes provide us with some insight into the extent of injuries and consequences of such accidents. Incidents include lasers that fail to stop after the foot pedal has been released; burns to lips, tongue and cheeks; firemen entering a surgery in response to a smoke alarm, unaware that a laser was in operation. Other incidents include injuries due to the laser beam being reflected off a droplet. Incidents specific to eyes include an injury because the manufacturer sent the doctor the wrong goggles specific to the laser wavelength being used and the doctor did not double-check the eyewear designation. Another recorded incident involved a university assistant suing for $39 million after she sustained a laser eye injury in a laboratory setting. A key factor in her case was that the professors were reported as not adhering to wearing the safety goggles, giving subordinates the impression that the protective eyewear was not necessary. The assistant settled for $1 million. These are just some

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**Table 1: Laser Classification, Power Output, and Risk Analysis**

<table>
<thead>
<tr>
<th>Laser Class</th>
<th>Maximum Output</th>
<th>Use in Dentistry</th>
<th>Possible Hazard</th>
<th>Safety Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>40 µWatts (blue)</td>
<td>Laser caries detection</td>
<td>No implicit risk</td>
<td>Blink response</td>
</tr>
<tr>
<td>Class IIM</td>
<td>400 µWatts (red)</td>
<td>Scanner</td>
<td>Possible risk with magnified beam (Class IM)</td>
<td>Laser safety labels</td>
</tr>
<tr>
<td>Class II</td>
<td>1.0 milliWatt</td>
<td>Aiming beams</td>
<td>Possible risk with direct viewing</td>
<td>Sight aversion response</td>
</tr>
<tr>
<td>Class IIM</td>
<td>Laser caries detection</td>
<td></td>
<td>Significant risk with magnified beam (Class IIM)</td>
<td>Laser safety labels</td>
</tr>
<tr>
<td>Class IIIR</td>
<td>Visible 5.0 milliWatts</td>
<td>Aiming beams</td>
<td>Eye damage</td>
<td>Safety eyewear Safety personnel Training for Class IIIR and IIIB lasers</td>
</tr>
<tr>
<td></td>
<td>Invisible 2.0 milliWatts</td>
<td>Low-level lasers Photodynamic antimicrobial chemotherapy devices</td>
<td>Eye damage</td>
<td>Safety eyewear Safety personnel Training for Class IIIR and IIIB lasers</td>
</tr>
<tr>
<td></td>
<td>0.5 Watt</td>
<td>Photodynamic antimicrobial chemotherapy devices</td>
<td>Maximum output may pose slight fire and skin risk</td>
<td>Safety eyewear Safety personnel Training for Class IIIR and IIIB lasers</td>
</tr>
<tr>
<td>Class IIIB</td>
<td>No upper limit</td>
<td>Mucosal scanning chemofluorescent devices</td>
<td>Eye and skin damage</td>
<td>Safety eyewear Safety personnel Training for Class IIIR and IIIB lasers</td>
</tr>
<tr>
<td>Class IV</td>
<td>All surgical lasers</td>
<td></td>
<td>Nontarget tissue damage</td>
<td>Safety eyewear Safety personnel Training and local rules Possible registration to comply with national regulations</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fire hazard</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Plume hazard</td>
<td></td>
</tr>
</tbody>
</table>
examples of the nature of laser injuries that can occur, the majority of which can be traced back to poor adherence to established safety protocols.

**LASER CLASSIFICATIONS**

All lasers used in dentistry are categorized with regard to the potential for damage, extending from Class I lasers, which may pose no implicit risk, to Class IV lasers for which all safety measures are applicable. Regardless of the class of laser being used, it is advised that one should never look directly into a laser beam, even if it is considered to be “eye-safe.” The classification ascends from Class I through Class IV, with Class I being considered eye-safe and Class IV being the most dangerous. However, with the increased use of magnification devices – loupes and microscopes – there is a potential for laser beams to be magnified and/or focused. Consequently, Class II M and Class II IM contain refinements.

Class II IR and II IB lasers are generally low-level instruments, whose wavelengths are in the red part of the electromagnetic spectrum and whose energy range lies between 1 and 500 milliWatts. They require safety personnel to monitor the Nominal Hazard Zone (NHZ), eye protection, and training. Class II IR was recognized to include those continuous-wave lasers that may emit up to five times the power of Class I and II lasers. These lasers pose significant risk of eye damage, and the eyewear must be rated at minimum Optical Density (OD) in the United States (U.S.) or European L6A standard. It is the laser manufacturer’s responsibility to provide the numerical value of the OD, in the operator’s manual, specific to the laser being used.

Table 1 provides an outline of the basic classes of lasers, the delineated emission parameters, examples of uses of each class within dentistry, risks posed to unprotected tissue, and safety measures. For clarification, it should be noted that the blink response is one of the responses that is encompassed within the aversion response. The aversion response consists of blinking and turning one’s head away from the beam path.

Class IV lasers, which are surgical devices, require safety personnel to monitor the NHZ, eye protection, and training. These lasers pose significant risk of damage to eyes, any nontarget tissue, and can produce plume hazards. Plume, in the context of this paper, is defined as the gaseous by-products and debris from laser-tissue interaction. It can have a smoky appearance or be completely invisible to the naked eye. With Class IV lasers, eyewear must be rated at a minimum OD 5.

It is the laser manufacturer’s responsibility to ensure that the device class is clearly marked on the laser machine and in certain countries it is required to post such information at all access points to the area in which the laser is being operated. It is the responsibility of the Laser Safety Officer (LSO) to ensure that the safety measures appropriate to each laser class are applied and made known to all staff. It is not the manufacturer’s responsibility to provide the dentist with training in this aspect. However, in the United States, federal regulations require manufacturers to provide certain safety information related to their laser to the laser operator’s manual. The computation, in feet or meters, of the NHZ of the laser is a calculation that is generally beyond the scope of the dentist or LSO.

Monitoring and calculating the NHZ are two different issues. It is the manufacturers’ responsibility to calculate what the NHZ distance is and have that information posted in the operator’s manual. It is the LSO’s responsibility to read the manual, ensure that the NHZ around the laser in the dental practice is identified, and personnel adhere to the safety measures.

**HAZARDS**

Laser devices, regardless of class, should be handled with care. With regard to those classes – IIIB and IV – that pose predictable or instantaneous risk, there are dangers associated not only with the laser beam itself, but also arising from the device (electrical, cables, air and/or water supplies) and chemicals either associated with the laser or the ablation of target tissue. Laser hazards may be listed as follows:

- **Optical**
- **Nontarget oral tissue**

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**GLOSSARY**

**NHZ**: Nominal Hazard Zone. This is the space within which the Maximum Permissible Exposure (MPE) is being exceeded.

**MPE**: Maximum Permissible Exposure. This represents a value of exposure to laser energy above which a risk of target damage may occur. MPE values are applied to the unprotected eye and skin.

**OD**: Optical Density. The ability of the glass or polycarbonate shield to attenuate the laser beam. The opacity of the protective filter.

**NOHD**: Nominal Ocular Hazard Distance. That distance from the emission port of the laser beyond which any exposure is within MPE values.
Skin
Chemical
Fire
Other collective hazards.

The concept of laser beam collimation may be considered theoretical, as in practice most laser beams exiting a delivery system will undergo some divergence with distance. Based on the power output, amount of divergence, and beam diameter and configuration, a Nominal Ocular Hazard Distance (NOHD) can be assessed.7

The possible risk to human tissue is assessed with regard to the Maximum Permissible Exposure (MPE). This is a value of exposure limit above which tissue damage may occur. The MPE can be applied relative to laser wavelength, power output, beam diameter, possible focusing of the beam, and target and nontarget tissue or structures.8-9

Within a certain space around a Class IV laser, the level of laser radiation that a person is being exposed to is above the MPE. Within this area, called the Nominal Hazard Zone (NHZ), protective measures must be taken. Many factors determine how large the NHZ area is. For example, an 810-nm diode laser with a maximum power output of 3 Watts will have a different NHZ than another 810-nm diode laser with 5 Watts of maximum output power. Therefore, it is not correct to say that the NHZ for an 810-nm diode laser is, for example, 8 feet for all diode lasers. The same can also be said for other laser wavelengths; it is incorrect to say that the NHZ for all Er:YAG lasers is 2 feet. The manufacturer has the responsibility of informing the dentist and LSO of the dental laser’s specific NHZ by publishing this information in the operator’s manual.

EYE HAZARDS

The eye is composed of pigmented and nonpigmented tissue that will absorb incident laser radiation relative to the wavelength being used. Damage from a laser beam may be due to direct exposure of the unprotected eye or diffuse reflection and is ever-present in those situations where wavelength-specific protective eyewear is not worn. Damage also depends on the type of laser being used, since a free-running pulsed laser will cause more damage than a continuous laser of equal power.10 This is because the output power of a free-running pulsed laser can achieve high peak power surges in a short pulse followed by long off-time durations. Its peak power is considerably greater than its average output power. For a continuous-wave laser, the output power and the peak power are the same, regardless of whether it is used in a continuous or gated mode. In addition, the ability of the eye’s lens to focus incident light may significantly increase the hazard posed by those wavelengths that may enter the eye.11 In current clinical dental use, shorter laser wavelengths (visible to near-infrared, 400-1400 nm), being relatively nonabsorbed by water, may result in retinal burns in the area of the optic disc. Some visible wavelengths may selectively damage green or red cones in the retina, producing color blindness. In addition, the 700-1400-nm wavelengths can cause lens damage.

The second group of wavelengths, the longer wavelengths (mid to far-infrared, 1,400-10,600 nm) have high absorption in water, and corneal, aqueous, and lens damage is associated with these wavelengths.12 Consequently, it is mandatory that all personnel (clinician, assistant, and patient) within the controlled area of Class IIIB, IIIR, and IV laser use should employ suitable eye protection during laser procedures. Measures must be taken to protect the eyes of the staff and patients when the MPE is exceeded, i.e., when the dental laser is on and people are within the NHZ. Eyewear should be constructed of wavelength-specific material to attenuate the laser energy or to contain the energy within MPE values. Standards that specify the nature and suitability of laser protective eyewear are contained in ANSI (ANSI Z136.1 – 2007) for North American users, EN 207/208 for European users, and IEC (IEC 60825) for all other regions. The manufacturer’s mark must be imprinted on the eyewear. The wavelength or wavelengths that the protective eyewear is specific for must be stamped on the
Glossary

DIR: Ability of the glass or polycarbonate to attenuate the beam relative to the emission mode of the laser for which the eyewear is intended, using coding “D” (continuous mode), “I” (pulsed mode), “R” (Q-switched mode).

L6A: Defines the suitability for the eyewear within clinical, industrial, or research conditions.

DIN: Direct Impact Number. A standard for the glass or polycarbonate shield against beam damage, relative to a 10-sec exposure (continuous wave) or 100 pulses (free-running pulsed emission mode).


Table 2: Eye and Skin Hazards of Dental Lasers

<table>
<thead>
<tr>
<th>LASER</th>
<th>EYE STRUCTURE</th>
<th>EYE DAMAGE</th>
<th>SKIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon 488-514 nm</td>
<td>Retina</td>
<td>Retinal Lesion</td>
<td></td>
</tr>
<tr>
<td>Caries detection and oral pathology cytofluorescent devices 630-900 nm</td>
<td>See below*</td>
<td>Retinal Lesion</td>
<td>Retinal Burn and Cataract (above 700 nm)</td>
</tr>
<tr>
<td>Diode 810-980 nm</td>
<td>Retina</td>
<td>Retinal Burn</td>
<td></td>
</tr>
<tr>
<td>Nd:YAG 1064 nm</td>
<td>Lens (above 700 nm)</td>
<td>Cataract</td>
<td></td>
</tr>
<tr>
<td>Ho:YAG 2100 nm</td>
<td>Lens</td>
<td>Cataract</td>
<td>Aqueous Humor</td>
</tr>
<tr>
<td>Er,Cr:YSGG 2780 nm</td>
<td>Lens</td>
<td>Cataract</td>
<td>Aqueous Humor</td>
</tr>
<tr>
<td>Er:YAG 2940 nm</td>
<td>Cataract</td>
<td>Aqueous Humor</td>
<td>Aqueous Flare</td>
</tr>
<tr>
<td>CO2 10,600 nm</td>
<td>Cornea</td>
<td>Corneal Burn</td>
<td></td>
</tr>
</tbody>
</table>

* Class I and II caries-detection lasers may become hazardous to the retina when viewed through optical aids, e.g., eye loupes and microscopes, as such magnification instruments can make a diverging beam more hazardous.

Glass or side shields. If the eyewear is marked as 810 nm – 2890 nm, then this means that the eyes exposed to all wavelengths between these two outer limits are protected. If one line states 810 nm and then underneath 2890 nm is stamped, it means that eyes are protected only against these two wavelengths and no protection is provided for wavelengths in between.

In addition, the OD is required to be stamped clearly onto the glass or polycarbonate side frames for North America while references to the OD, CE mark, operation mode (DIR), protective grade (L6A), and Direct Impact Number (DIN) are displayed in Europe.

Please refer to the glossary provided for additional information. Practitioners using loupes must wear the appropriate protective insert or shield. Glasses and goggles must cover the entire periorbital region, be free of any surface scratches or damage, and be fitted with suitable side panels to prevent diffuse laser beam entry. Practitioners using a microscope must fit the appropriate filters and maintain close eye contact with the oculars.

The protocol for use is “patient first on and last off.” This means that as soon as the patient is seated in the dental chair, he or she is to put on the appropriate laser eyewear, which is not to be taken off until the patient is leaving the dental operatory at the end of the procedure. The dental operatory personnel must don the eyewear prior to the laser being turned on and not take them off until the laser is switched off or put into standby mode.

Care must be taken when cleaning laser eyewear and side shields so that their protective coating is not destroyed. The eyewear should be washed with antibacterial soap and dried with a soft cotton cloth in between procedures and patients. Disinfecting solutions generally applied to dental surfaces are too caustic and should be avoided. The eyewear must be inspected frequently to determine whether there is any breakdown (lifting / cracking / flaking) of the protective material that would render the eyewear to be useless.

NonTarget Oral Tissue Hazards

The constraints of the oral cavity pose specific risks in access and
accidental damage to adjacent or nontarget tissue. The close approximation of multiple chromophores (molecular compounds that absorb light or laser energy such as hemoglobin, water, hydroxyapatite, and melamin in oral tissue) demands care during the use of any surgical laser wavelength to avoid unintentional vaporization of other tissues. During any surgical ablation procedure using laser energy, attention is required to focus the beam onto the target tissue and avoid accidently damaging adjacent tissues. Anodized, dull, nonreflective, or matte-finished instruments should be employed. Coated (i.e., ebonized) instruments should be inspected regularly to ensure integrity of the coating. Glass mirrors should not be used because they absorb heat from the laser energy and may shatter. Stainless steel or rhodium mirrors may be used safely, providing measures are taken to minimize possible unwanted reflection.

Parallel monitoring of the adjacent tissues by all dental staff present at the time of treatment is to be ensured. Assistants need to be trained in recognizing adverse or unexpected tissue change as they play a role in monitoring the dental situation, especially if the dentist is using a microscope or other accessory that might reduce the clinician’s wider field of vision.

SKIN HAZARDS
Any potential for damage to the skin through inadvertent exposure to Class III B and IV lasers will be relative to the ablation threshold of the skin structure and the incident laser energy. Subablative power levels will pose little threat, other than reversible tissue warming. Visible and near-infrared wavelengths (400-1400 nm) have the potential to pass through the epidermis into the superficial and deeper structures respectively. Mid-to far-infrared wavelengths (1400-10,600 nm) will interact with surface structures. The governing factor in structural damage is the particular laser wavelength’s absorptive potential relative to the tissue elements (chromophores) such as pigment (shorter wavelengths) and water (longer wavelengths), together with the power density value of the laser beam, duration of laser exposure, and spot size. It is important that all those involved in the use of Class IIIB and IV lasers are adequately protected against inadvertent skin exposure.

CHEMICAL HAZARDS
Laser plume poses a significant hazard and occurs as a result of the development of aerosol by-products due to laser-tissue interaction. These products can contain particulate organic and inorganic matter including viruses, toxic gases, and chemicals. This is not unique to lasers, as it has been known that surgical instruments, such as electrosurgical equipment and dental handpieces, create surgical debris. American National Standard for the Safe Use of Lasers in Health Care Facilities states that the hazard area for laser-generated airborne contaminants (LGACs) may be greater than the laser’s identified NHZ. Examples of the products contained in LGAC include human papilloma virus, human immunodeficiency virus (suspected), carbon monoxide, hydrogen cyanide, formaldehyde, benzene, acrolein, bacterial spores, and cancer cells.

Of particular importance in restorative dental procedures, other hazardous products may be present in the plume. During removal of composite resin with an erbium laser, along with the ejected whole resin particles, small amounts of free methacrylate monomer can be produced. Furthermore, although not an indication for use, directing the erbium laser’s energy onto amalgam can produce mercury vapor, according to an in vitro study. This same precaution also applies to other lasers.

The hazard presented by the LGACs may include eye irritation, nausea, breathing difficulties, vomiting, and chest tightness together with the possibility of transfer of infective bacteria and viruses. To combat such risk, regular surgical protective clothing must be employed and specific fine-mesh face masks capable of filtering 0.1-micron particles must be worn. Use of high-speed evacuation must also be used. It has been determined that for carbon dioxide laser surgery, the evacuation tube should be held as close as 1 cm from the target site; at 2 cm, the evacuation ratio had diminished by 50%.

FIRE HAZARDS
The high temperatures that are possible in the use of Class IV and certain Class IIIB lasers can themselves either cause ignition of material and gases or promote flash-point ignition. ANSI Z136.3 has allowed gaseous conscious sedation procedures, such as the use of a nosepiece to deliver oxygen and nitrous oxide mixtures to be used during laser operation. However, a closed-circuit delivery system must be used and a scavenging system must be connected to the high-volume evacuation to minimize gas leakage. Within the NHZ, use of aerosols, alcohol-soaked gauze, and alcohol-based anesthetics are to be avoided. Consequently, it is important to request that the patient remove any lip products that may contain an oil-based substance that is considered flammable, such as petroleum jelly. Additionally, tissue cleansing or preparation agents that contain alcohol or other flammable chemicals carry specific risk of burning during laser use. If the patient carries an oxygen tank, then the laser should not be utilized for the dental procedure, unless the patient will remain...
comfortable with the oxygen turned off and the nose cannula removed during the laser portion of the procedure.

With general anesthetic procedures, there are three aspects to be considered:
1. Ignition sources (of which lasers are an example)
2. Fuel sources (gauze, drapes, preparation fluids, alcohol, and anesthetic gases)
3. Oxygen-enriched atmosphere (more than 21% oxygen).

The laser energies used in tissue ablation may surpass the flash point of some anesthetic aromatic hydrocarbons used in general anesthesia, and the presence of oxygen and nitrous oxide will support any combustion. Many materials that are not normally flammable may burn in an oxygen-enriched atmosphere. Endotracheal tubes need particular consideration to prevent the laser beam from burning a hole in the tube and combusting with the gases. Consequently, the tubes should be resistant to the laser beam and have suitable coating, a wavelength-specific reflective coating if possible, to prevent the possibility of combustion of the material and subsequent airway burns. Care should also be taken to prevent the build-up of blood onto endotracheal tubing, as this may lead to an increased fire hazard.

OTHER HAZARDS
Additional hazards associated with laser use include service and mechanical hazards. Potential service hazards include electrical, water, and air supply lines and cables, as well as connectors and filters. The laser should be serviced regularly according to the manufacturer’s recommendations and only by qualified personnel. The practitioner should inspect the supply lines and cables, clean and maintain the external portions of the laser, and change necessary filters or other user-serviceable items. In addition, many surgical lasers use a coaxial air or water supply which may be under pressure. No attempt should be made to access internal parts of the machine during use. Capacitors can retain an energy charge, even when the laser is no longer connected to the electrical supply outlet.

Mechanical hazards include moving parts (e.g., articulating arms). Laser machines employ multi-level safety features (fuse plugs, interlocks, pressure relief valves, and warning lights) to inactivate the machine in the event of a component failure. Additional hazards may exist such as heavy articulated-arm delivery systems or the risk of needle-stick injury with fine quartz fiber-optic tips. Care must be taken around the cables and wires associated with the laser, as tripping over and wrenching these cables and fibers can be dangerous. Some machines are portable and, when moved, should be reassembled completely, ensuring stability.

INFECTION CONTROL
In the United States, the Centers for Disease Control and Prevention (CDC) have established infection control guidelines in a 2003 report. Lasers in dental practices are to be considered as another dental instrument. Dental practitioners and their team must follow standard precautions. Standard precautions include the use of personal protective equipment (PPE) (e.g., gloves, masks, protective eyewear or face shield, and gowns) intended to prevent skin and mucous membrane exposures.

Specific to lasers, any reusable fibers and tips must be heat-sterilized along with their handpieces, and not wiped with a high-level disinfectant. Any debris on the end of the tip must be removed and/or cleaved off the end of the fiber to ensure effective sterilization. The operator’s manual should contain recommendations about the sterilization process. For example, it is suggested that one does not sterilize the high-speed, lubricated dental handpieces at the same time as the laser fibers so as to eliminate the possibility of oil from the handpieces leaking through the bag onto the fibers. Disposable tips must be put into sharps containers, along with cleaved pieces of the fiber. Plastic or metal cannulas

GLOSSARY

Critical Instrument: Any instrument that penetrates soft tissue, contacts bone, enters into or contacts the bloodstream, or other normally sterile tissue. Examples include surgical instruments, periodontal scalers, and scalp blades.

Semicritical Instrument: Any instrument that does not penetrate soft tissue, contact bone, bloodstream, or sterile tissue but can contact mucous membranes. Although dental handpieces are considered semicritical, the U.S. Centers for Disease Control and Prevention state that they should be heat-sterilized and not high-level disinfected.

High-Level Disinfection: Process that inactivates vegetative bacteria, mycobacteria, fungi, and viruses but not high numbers of bacterial spores.

Sterilization: Use of a physical or chemical procedure to destroy all microorganisms including substantial numbers of resistant bacterial spores.
fitted to the handpiece and used to position the fiber optic should be disposed of in regular trash. Removable or wipeable barriers are recommended to be placed over operational controls on the laser. Care should be shown to the possibility of contamination of all laser hardware; protective sleeves and barriers (e.g., syringe covers, sensor protector sheaths, transparent universal sticky barrier covers) should be utilized where possible. The laser and surfaces within the dental environment should be wiped with high-level disinfectant following the procedure. Any cleaver used on a contaminated fiber should also be heat-sterilized.

**ENGINEERING CONTROLS**

Through successive internationally agreed regulations, laser devices (specifically but not exclusively Class IIIB and IV) have built-in safety features. These regulations are designed to prevent unauthorized use and protect those involved in laser applications. Engineering controls are set in place by the manufacturer and are always preferred, where possible, over administrative controls. Safety features include the following:

- Locked unit panels to prevent unauthorized access to internal machinery
- Covered foot switch, to prevent accidental operation
- Delayed response from the foot switch (to prevent accidental operation, e.g., unintentional stepping on the foot switch)
- Casters, if present, must be lockable
- Remote interlocks. These constitute a connection between a closed door and the laser. Should the door be opened during laser operation, the remote interlock will shut down the laser
- Key or password protection to prevent the laser from being operated when authorized personnel are not present
- Emission port shutters to prevent laser emission until the correct delivery system is attached
- Emergency stop switch or button – visible and easily located so that the laser can be shut down in an instant without the operator having to go through a lengthy process
- Control panel and display to ensure correct emission parameters are set
- Laser software diagnostics and error messages. Internal systems within the laser that shut down operations when any component that is not functioning correctly is detected
- Specific laser standby and laser-emission modes
- Time-lapsed default to standby mode so that if a laser left in “ready” mode is not used within a certain time frame, the laser will revert to “standby” mode. Stepping on the foot switch in “standby” mode will not initiate the laser to operate
- Audible sound that is distinctive to the laser when it is in operation
- Visible signs on the laser, such as lights which warn whether the laser is in standby mode or is being used.

**ADMINISTRATIVE CONTROLS**

In addition to the manufacturer’s engineering controls, additional safety measures are also required in order to minimize the risk of an adverse event. In this context, an adverse event is defined a serious and undesirable experience or outcome (including death, life-threatening injury, disability, hospitalization, and intervention to prevent those outcomes) that results from a dental laser marketed in accordance with the standards set forth by the regulations governing its use within that specific country or region. It is essential that all surgical lasers be used with responsibility and due regard to their potential safety risk. These administrative policies supplement the aforementioned mechanisms in order to facilitate a safe laser environment and require the appointment of a Laser Safety Officer (LSO) to oversee their implementation. Policies include:

- Establishing written Standard Operating Procedures (SOPs) for the dental practice, as required by ANSI Z136.1 – 2007 and other national standards as they may apply
- The appointment of an LSO with specific responsibilities, as follows:
  - Serves as the “keeper of the key” to secure the key in a safe place when the laser is not in operation
  - Authorized to shut down laser operation. This authority is to be recognized and respected in the dental office regardless of the dental employee position held by the LSO
  - Keeps current with safety standards, such as OSHA, ANSI, IEC (or those of the appropriate country) through educational meetings and literature review, and updates this information with the dental practice
  - Supervises the education and training of the dental team
  - Assists with evaluation when a new laser is needed
  - Understands the operational characteristics of the laser(s) in the practice
  - Using the manufacturer’s NHZ, identifies this area within the dental office in accordance with the laser being used
  - Ensures correct warning signs are posted at every entryway into the operator in which the laser is being used
  - Ensures that the laser signs are taken down after the procedure is completed, and not left up as “wallpaper”
  - Oversees the protective eyewear
• Ensures the correct wavelength-specific eyewear is being worn within the NOHD
• Ensures that the policy of patient eyewear “first-on and last-off” is adhered to. The policy for the dental team is “on before the laser is initiated and off after the laser application is finished,” and the laser is turned off or placed in standby mode
• Ensures the laser is being operated by authorized personnel only
• Understands the operational characteristics of the laser(s)
• Knows the output limitations of the device
• Determines the controlled area and the potential hazard and nonhazard zones
• Ensures laser maintenance, beam alignment, and calibration
• Is familiar with the biological and other potential hazards of the laser
• Supervises medical surveillance and incident reporting
• Keeps a log of recorded laser use and parameters employed
• Ensures proper test-firing of the laser prior to admission of the patient into the operatory.

Laser test-firing is a safety measure designed to establish that the laser is working correctly and that there is patency of the delivery system. Test-firing should be carried out by the clinician or LSO prior to every procedure and before the patient is admitted to the controlled area. Protective eyewear is worn and all other safety measures met. The laser is directed toward a suitable absorbent material (e.g., water for longer wavelengths – 1400-11,000 nm, and dark-colored paper for short wavelengths – 400-1400 nm) and operated at the lowest power setting for the laser being used. Test-firing will demonstrate that the laser is functioning properly, all connections are securely in place, the delivery system is not damaged, and the laser beam is patent.

It is necessary to define a controlled area, within which all safety aspects pertaining to laser use are enforced. The LSO must follow the operator’s manual regarding the dimensions or limits of the controlled area. Dental clinics with multichair, open-plan environments need to address the physical dimensions and administrations of their controlled area in greater detail. Within the controlled area, all surfaces should be nonreflective, and measures should be taken to ensure that all supply cables for the laser along with its delicate delivery system are protected from inadvertent damage. A fire extinguisher should be sited for easy access.

The LSO is required to oversee the training of the entire dental team with regard to lasers, including the nonuser and administrative staff. It is imperative that nonuser team members in the dental office are educated at some level with regard to the laser equipment and have received training on aspects of laser safety as they apply to their dental office. Regulatory agencies recognize the essential nature of appropriate training in laser use and there is an implied necessity that clinicians should receive training as part of their duty of care and dental licensing.

FURTHER READING

Further reading is recommended in order to ensure that the clinician is complying with national, federal, or regional regulations:


The Standard Operating Procedure is a living, written document that outlines the existence and identity of laser devices within a given practice setting, personnel authorized to use the laser, and safety measures to address the hazards associated with the lasers in that particular dental practice. It contains all the local and national rules, including those set out in the aforementioned administrative controls. In the United States, ANSI Z136.1 – 2007 requires every dental practice with a laser to have such a document and many countries or regions have similar requirements.

The Academy of Laser Dentistry adopted the Curriculum Guidelines and Standards for Dental Laser Education which defines a core of knowledge appropriate to the safe use of lasers in dentistry. All those clinicians passing proficiency examinations with the Academy will satisfy an acceptable level of competence in laser safety, and nonclinicians may take proficiency examinations to be recognized as laser safety officers.

CONCLUSION
Laser use in dentistry is proven to be beneficial in treating a wide range of dental conditions as well as a therapeutic tool in tissue management. The dynamics of laser energy beams pose general risks to non-oral tissues and the immediate environment of such use must be deemed at risk from direct or scattered exposure. Safety measures have been devised to safeguard those personnel – staff and patients – who may be involved in dental treatment using lasers. Most safety measures are the product of official regulatory bodies such as ANSI, OSHA, FDA, and IEC, but additional measures may be the product of individual needs within particular dental offices and consequently recorded in local rules. The reader is encouraged to consult these regulatory bodies as they may apply on a national or regional basis, to ensure a correct and responsible compliance with all laser safety measures in the treatment of dental patients. The analysis of general and specific risk during laser use has been addressed through many statutory instruments and all clinical procedures should be measured against such standards, in order to offer the maximum protection for the patient, clinical staff, and those within the immediate environment.

AUTHOR BIOGRAPHY
As business manager for the dental office of Dr. Peter Pang, Ms. Caroline Sweeney is responsible for the effective operation and promotion of the laser practice. Degrees in Business and Science combined with 18 years of experience in the medical/dental field provide her with a unique foundation for this role. As a faculty member of the Santa Rosa Junior College dental auxiliary program, she plays an active part in encouraging students to embrace advancements in dentistry. She has achieved Advanced Proficiency in 3 laser wavelengths and is the chair of the Laser Safety Committee for the Academy of Laser Dentistry. Ms. Sweeney may be contacted by e-mail at Caroline@SonomaCosmeticDentist.com.

Disclosure: Ms. Sweeney receives a salary for being an adjunct faculty member at the Santa Rosa Junior College. She does not receive any compensation for lecturing with Dr. Peter Pang.

REFERENCES


Proceedings of the ALD/FDA 2008 Joint Symposium on Lasers and Light-Based Technology Utilization in Dentistry

Silver Spring, Maryland • Monday, December 8, 2008  8:00 a.m. – 5:00 p.m.

Donald J. Coluzzi, DDS, Portola Valley, California

OVERVIEW AND EDUCATIONAL PURPOSE

The Academy of Laser Dentistry (ALD) and the United States Food and Drug Administration (FDA), Center for Devices and Radiological Health (CDRH) coordinated a day-long series of presentations in Silver Spring, Maryland, that focused on how lasers and light-based technologies interact with oral tissues, the impact they presently have in the practice of dentistry, and some of the current research of these technologies that could lead to new future surgical, preventive, diagnostic, and healing applications. The presenters were some of the most respected and leading professionals in their respective fields and include practicing clinicians, academicians, and researchers from around the country.

The morning session included discussions on how lasers were developed for dentistry, their impact on soft and hard tissues, their use in preventive applications, and their role in the practice of dental hygiene. A visible light source used for screening of oral soft tissue and a laser optical coherence tomography device were presented as novel diagnostic instruments.

The afternoon series continued with the research and potential use of low-power lasers or incoherent sources that produce regenerative therapy to a wide spectrum of medical and dental problems. Finally there was a short open session for discussions with audience participation on the day’s topics.

The audience of approximately 50 individuals included dentists, academicians, researchers, government and military professionals, and representatives of related dental organizations.

PRESENTATIONS AND BIOGRAPHIES

There were 12 presentations and a closing discussion session. The abstracts and speaker biographies are listed below in the order in which they appeared on the program.

PRESENTATION 1: WELCOME AND INTRODUCTIONS.
THE ROLES AND MISSIONS OF THE ALD AND THE FDA

Welcome: Ronald W. Waynant, PhD
Senior Optical Engineer, FDA/CDRH

Past President of the Academy of Laser Dentistry

Abstract
A brief overview of the Academy of Laser Dentistry will be presented. Highlights include a short description of the history and mission of the ALD, the make-up of the administration, executive committee, board of directors, and working committees.

Biography
Dr. Ronald W. Waynant is a senior optical engineer at the Food and Drug Administration, Rockville, Md. He was an adjunct professor of electrical engineering at the Catholic University of America, Washington, DC and taught a graduate-level laser course for 14 years there. He currently serves on the advisory board to the Catholic University Department of Electrical Engineering. He is now an adjunct associate professor at the Uniformed Services University for the Health Sciences in Bethesda, Md. Most recently, he has been working on laser therapy mechanisms and various sources for and uses of laser therapy. He is also interested in laser medicine, infrared fiber optics, and laser-generated X-rays for medical imaging. Dr. Waynant has edited six books in the electro-optics and laser medical areas and four
special issues of *IEEE Journal of Special Topics in Quantum Electronics*. He has organized eight conferences for the Engineering Conferences International organization on lasers, laser medicine, and laser therapy. He has also served on IEEE Lasers and Electro-Optics Society (IEEE LEOS) Board of Governors for 20 years. His research work in the past 15 years has been funded by agencies such as the Air Force Office of Scientific Research (AFOSR), Office of Naval Research (ONR), Defense Advanced Research Projects Agency (DARPA), and National Science Foundation (NSF).

He is an elected Fellow of the American Institute of Medical and Biological Engineers (1996), an elected Fellow of the Institute of Electrical and Electronic Engineers (1987), an elected Fellow of the Optical Society of America (1988), an elected Fellow of American Society for Laser Medicine and Surgery and currently a member of the Board of Directors, and an elected Fellow of the Washington Academy of Sciences. He has published more than 110 journal papers and has given more than 120 presentations. He also has 10 patents. He has recently retired as editor-in-chief of the *IEEE Circuits & Devices* magazine after 20 years. Dr. Waynant may be contacted by e-mail at Ronald.waynant@fda.hhs.gov.

**Disclosure:** Dr. Waynant has Cooperative Research and Development Agreements (CRADAs) with Raydiance and NanoSonic. He receives a small amount of funding from NanoSonic. Both of these CRADAs have been approved by FDA and signed by the Commissioner.

**Biography**

Dr. Donald Coluzzi, a 1970 graduate of the University of Southern California School of Dentistry, is an associate clinical professor in the Department of Preventive and Restorative Dental Sciences at the University of California San Francisco School of Dentistry. He is a charter member and past president of the Academy of Laser Dentistry, and is currently the editor-in-chief of the *Journal of Laser Dentistry*. He has used dental lasers since early 1991. He has Advanced Proficiency in Nd:YAG and Er:YAG laser wavelengths. Dr. Coluzzi is the 1999 recipient of the Leon Goldman Award for Clinical Excellence and the 2006 Distinguished Service Award from the Academy, a Fellow of the American College of Dentists, and a Master of the Academy of Laser Dentistry. Dr. Coluzzi has delivered presentations on lasers worldwide, co-authored two books, and published several peer-reviewed articles. Dr. Coluzzi may be contacted by e-mail at don@laser-dentistry.com.

**Disclosure:** Dr. Coluzzi has no dual commitments as defined in the ALD Disclosure Policy. He is being reimbursed for travel and hotel expenses by the Academy of Laser Dentistry.

**Abstract**

The presentation will provide the audience with a historical overview of the U.S. dental laser market. It will set the stage for the remainder of the 2008 Joint Symposium speakers. The two-part presentation will first review the significant FDA marketing clearances beginning with Sunrise Technologies’ soft tissue clearance of May 1990. The second segment will concentrate on the U.S. dental laser market and the factors that helped place over 28,000 instruments in dental offices.

**Biography**

Dr. Terry Myers has been researching the use of lasers in dentistry since 1983. His early work resulted in the development of the Nd:YAG dental laser, which he invented and patented with his ophthalmologist brother, Dr. William D. Myers. It is the first laser in the world designed specially for general clinical dentistry. Since graduation from the University of Detroit Dental School in 1973, Dr. Myers has maintained a private practice in the metro Detroit area of Michigan. He has held teaching positions at various universities in the Detroit area and is currently an adjunct associate professor, University of Detroit Mercy School of Dentistry. He also has interests in veterinary dentistry, and has delivered dental care at the Detroit Zoological Parks. Dr. Myers has authored articles on his work and is an internationally recognized speaker, having conducted hundreds of laser dentistry and air abrasion lectures and workshops throughout the world. Dr. Myers may be contacted by e-mail at tdmdds@comcast.com.

**Disclosure:** Dr. Myers is cofounder and president of Incisive, LLC. He is being reimbursed for travel and hotel expenses by the Academy of Laser Dentistry.

**Presentation 3: Laser Interactions with Soft and Hard Oral Tissues and Their Applications**

Michael Swick, DMD

Member, Board of Directors of the Academy of Laser Dentistry

**Abstract**

Laser-tissue interaction will be covered as a review for the attendees. The emphasis will be on a review of the interactions which relate most notably to dentistry and common dental usage. The near-, mid-, and far-infrared ranges are applied daily in many dental
practices worldwide as a result of the applicability, availability, and affordability of present laser units. The myriad of applications will be discussed and demonstrated with the use of microscopic, high-definition video taken through a surgical operating microscope.

Biography
Dr. Michael Swick is a general dentist and has offices in Allison Park and Conneaut Lake, Pennsylvania. He practices microdentistry using air abrasion and lasers, working through a surgical operating microscope. He holds an Advanced Proficiency in the 980-nm and 2940-nm laser wavelengths and standard proficiency in CO2, Nd:YAG, 810-nm diode, 980-nm diode, Er:Cr:YSGG, and Er:YAG laser wavelengths through the Academy of Laser Dentistry. He is an Academy of Laser Dentistry certified educator as well as a Recognized Course Provider whose Standard Proficiency laser courses are accepted for Standard Proficiency Certification through the Academy of Laser Dentistry. He is currently serving on the board of directors of the Academy of Laser Dentistry, has served as the chairman of the Education committee, served on the Science and Research, Scientific Sessions, Nominating, and Constitution and Bylaws Committees. Additionally, he holds certification from St. Luke’s Medical Center in the Pinero Precardiac Surgery Protocol with lasers. Dr. Swick is a former Fellow in the American Society for Laser Medicine and Surgery where he has presented clinical papers. He has presented more than 350 continuing education and hands-on courses in dental lasers, both nationally and internationally. In addition he has presented clinical and scientific papers for the ALD, European Society for Oral Laser Applications (ESOLA)/Deutsche Gesellschaft für Laserzahnheilkunde (DGL), International Society for Lasers in Dentistry (ISLD), and SPIE. Dr. Swick may be contacted by e-mail at hiteddkr@aol.com.

Disclosure: Dr. Swick has lectured, provided training, and consulted for the BioLitec, HOYA ConBio, Sirona, Kavo, and Elexxion laser companies as well as LED Dental on the VELScope and the Institute for Laser Dentistry in Canada for whom he has lectured extensively on a per diem basis. He currently is a consultant, lecturer, and trainer for the Elexxion laser company and he receives a per diem for his efforts. He is being reimbursed for travel and hotel expenses by the Academy of Laser Dentistry.

Presentation 4: Preventive Applications
Peter Rechmann, Prof. Dr. Med. Dent. DDS, PhD
President of the Academy of Laser Dentistry
Professor and Director, Clinical Sciences Research Group, University of California San Francisco School of Dentistry

Abstract
This presentation will discuss two different areas where lasers can be used for preventive applications in dentistry. One is enhancing caries resistance of dental hard tissues after laser irradiation, the other relates to the use of lasers to prevent or slow the progression of periodontal disease. The successful use of a 9.6-µm CO2 short-pulsed laser in caries prevention in laboratory studies as well as in clinical trials will be presented. A historical background and comparisons to the use of other laser wavelengths for this indication will be offered. In the second part of the presentation the selective and efficient removal of microbial plaque and calculus in laboratory studies with lasers emitting in the blue spectral region will be reported. The clinical advantages of this application and its relevance in periodontal prevention and therapy will be described.

Disclosure: Dr. Rechmann has research grants from the National Institutes of Health (NIH). He has a consulting relationship and patent licensing agreements with Lares Research and affirms that these relationships will not influence his objectivity. In this presentation the 9.6-µm CO2 laser for enhancement of caries resistance is unlabeled and investigational as is the Alexandrite laser – for micro plaque/calculus removal and the argon laser in laboratory use. He is being reimbursed for travel and hotel expenses by the Academy of Laser Dentistry.

Presentation 5: The Utilization of Light-Based Technologies in the Practice of Dental Hygiene
Angie Mott, RDH
Member, Board of Directors of the Academy of Laser Dentistry

Abstract
This presentation including case studies and statistics will allow the attendees to see how a soft tissue dental laser in the hands of a dental hygienist can be a tool that provides wonderful treatment
options to allow the ultimate dental health. These case studies will show the steps taken to reduce the bacterial levels and restore the mouth to an optimal healthy situation as well as show how pain and swelling can be reduced with a soft tissue laser related with a herpetic lesion. Dental hygienists have a great opportunity to be in a co-diagnosis position. A dental hygienist should utilize other diagnostic aids, such as oral cancer evaluations, propose alternative periodontal treatment options, suggest restorative options that would contribute to overall dental health, and present any other pertinent patient issues to the doctor.

Biography
Angie Mott has been a clinical hygienist for more than 20 years. She is a member of the Academy of Laser Dentistry, where she obtained her Advanced Proficiency and Educator Status, and received her ALD Recognized Course Provider in 2007 and her Mastership with ALD in 2008. She currently serves as auxiliary chair for the ALD Board of Directors and serves on the Regulatory Affairs, Education, Membership, Advertising, and Scientific Sessions committees. Angie is a past presenter for the ALD and has had articles published in RDH and JPH magazines. She has worked with Nd:YAG soft tissue lasers since 2000, and diode soft tissue lasers since 2005. Ms. Mott may be contacted by e-mail at DABT4CU@aol.com.

Disclosure: Ms. Mott has no financial relationship with any organization or company relative to this presentation. She has in the past received honoraria or payment for consultation services from Ivoclar Vivadent and Biolase Technology. She is being reimbursed for travel and hotel expenses by the Academy of Laser Dentistry.

Presentation 6: Tissue Fluorescence (Autofluorescence) Role in the Diagnostic Process
Scott D. Benjamin, DDS
Vice-Chair, Education Committee of the Academy of Laser Dentistry
Working Group Chairman, ADA Standards Committee on Dental Products on Dental Lasers

Abstract
The accurate evaluation and assessment of the patient’s condition is the foundation of all healthcare decisions and is crucial in attaining successful outcomes and sustaining a high quality of life. This presentation reviews the basic science of autofluorescence and how it relates in oral screenings. In addition, it will discuss some of the various modalities utilizing autofluorescence in evaluating the tissue and other substances in the oral cavity. Although the emphasis will be on the oral cavity, it will also include a historical account and examples of tissue autofluorescence in general and present current techniques for the visualization of fluorescence in the lung, cervix, and skin. The talk is designed to illustrate the science and biophotonic mechanisms responsible for tissue autofluorescence and its correlation with abnormal conditions.

Tissue autofluorescence is produced by fluorophores in the oral cavity when stimulated with excitation light. In the case of blue light excitation, important epithelial fluorophores include the reduced form of nicotinamide adenine dinucleotide (NADH) and the oxidized form of flavin adenine dinucleotide (FAD) while important stromal fluorophores include collagen and elastin cross links. Also the fluorophore porphyrin, a bacterial endotoxin, has an autofluorescence emission if appropriately interrogated with light energy when evaluating both the hard and soft tissues of the oral cavity. The presentation will review the current understanding of the relative contributions these fluorophores have when the fluorescent signal is observed and illustrate how the signal changes with disease processes.

The presentation will also discuss some of the noninvasive modalities used in screening the oral cavity that illuminate the oral structures with visible light and allow for the observance of the resultant fluorescent response that is detected with the use of specialized filters, and how this information can be utilized by the clinician in the diagnostic process.

Biography
Dr. Scott Benjamin is in private practice in rural upstate New York, a visiting professor at the State University of New York (SUNY) at Buffalo School of Dental Medicine, and a research associate at the New York University College of Dentistry. He is an internationally recognized lecturer on oral cancer and advanced dental technologies and has published more than 150 articles on dental technology in over a dozen publications. Dr. Benjamin is presently a member of the editorial board of several prestigious peer-reviewed dental journals. He in an active member and Working Group chairman of both the American Dental Association Standards Committee on Dental Products (ADA-SCDP) and Dental Informatics (ADA-SCDI). Dr. Benjamin was a participant in the World Health Organization’s (WHO) Collaborating Centre for Oral Cancer and Precancer Working Group on “Potentially Malignant Oral Mucosal Lesions and Conditions: Terminology, Classification, Diagnosis, and Prognosis.” Dr. Benjamin may be contacted by e-mail at sbenjamin@dentalaim.com.

Disclosure: Dr. Benjamin has been a clinical consultant, advisor, and lecturer receiving honoraria for LED
Medical Diagnostics Inc., Vancouver, British Columbia, Canada and Sirona Dental Systems LLC, Charlotte, NC. He has also lectured for several laser and advanced dental technology companies for which he has received honoraria. He is being reimbursed for travel and hotel expenses by the Academy of Laser Dentistry.

**Presentation 7: Optical Coherence Tomography (OCT) Diagnostic Imaging**

Craig Gimbel, DDS
Past President of the Academy of Laser Dentistry

**Abstract**

Optical Coherence Tomography (OCT) is a new type of optical imaging that captures high-resolution, cross-sectional 2D and 3D images of the internal microstructure of oral hard and soft tissue, as well as dental restorative materials. By measuring the backscattering of 1310-nm light, image resolutions of 10 um can be captured in situ and in real-time on a computer monitor. It is analogous to ultrasound B, except that it uses noninvasive light instead of sound. The unique features of this technology enable a broad range of clinical and research applications in dentistry. Very early demineralization due to a carious lesion can be imaged and then followed as remineralization occurs. Other imaging capabilities include dysplasias and microstructural defects of the tooth and restorative material, early periodontal disease, dysplasias and precancerous lesions, endodontics, vertical root fractures, and orthodontics. OCT can speed up research by not having to rely on tissue removal. “Optical biopsies” permit frequent monitoring of oral tissue pathology and restorative material. The resultant images provide quantitative and qualitative information of high sensitivity and specificity for the clinician and researcher.

**Biography**

Dr. Craig Gimbel is the immediate past president of the Academy of Laser Dentistry. In 1993-1997, he was a principal investigator for the first FDA human hard tissue clinical trials for the erbium:YAG laser in dentistry. He was the recipient of the T. H. Maiman Award for excellence in dental laser research in 2002. Since 2002, Dr. Gimbel has been working on the development of optical coherence tomography for dentistry and has held a peer-reviewed manuscript on this subject recently published in General Dentistry. Dr. Gimbel may be contacted by e-mail at believe5154@optonline.net.

**Disclosure:** Dr. Gimbel has a financial relationship with Axsun, Inc. Optical Coherence Technology, University of Florida, and National Lab/University of California, Massachusetts Institute of Technology, University of Florida, and Axsun, Inc. Optical Coherence Tomography for dentistry is presently investigational as a diagnostic aid. He is being reimbursed for travel and hotel expenses by the Academy of Laser Dentistry.

**Presentation 8: Mechanisms of Low-Level Light Therapy (LLLT)**

Michael R. Hamblin, PhD
Associate Professor, Harvard Medical School
Principal Investigator, Wellman Center for Photomedicine at Massachusetts General Hospital

**Abstract**

This presentation will focus on the molecular and cellular mechanisms involved in low-level light therapy (LLLT). It is thought that red and near-infrared photons are absorbed by cytochrome c oxidase (unit four in the mitochondrial respiratory chain) and small concentrations of inhibitory nitric oxide may be photo-dissociated, thereby increasing respiration and ATP. Coincidentally with the increase in electron transport and in ATP, there has also been observed by intracellular fluorescent probes and electron spin resonance an increase in intracellular reactive oxygen species (ROS) such as superoxide, hydrogen peroxide, singlet oxygen, and hydroxyl radical. ROS scavengers, antioxidants and ROS quenchers block many LLLT processes. It has been proposed that light between 400 and 500 nm may produce ROS by a photosensitization process involving flavins, while longer wavelengths may directly produce ROS from the mitochondria. Several redox-sensitive transcription factors are known such as NF-kB and AP1, that are able to initiate transcription of genes involved in protective responses to oxidative stress. It may be the case that LLLT can be pro-oxidant in the short-term, but anti-oxidant in the long-term.

**Biography**

Dr. Michael Hamblin is a principal investigator at the Wellman Center for Photomedicine at Massachusetts General Hospital and an associate professor of Dermatology at Harvard Medical School. He was trained as a synthetic organic chemist and received his PhD from Trent University in England. His research interests lie in the areas of photodynamic therapy (PDT) for infections, cancer, and heart disease and in low-level light therapy (LLLT) for wound healing, arthritis, traumatic brain injury, and hair regrowth. He has published more than 90 peer-reviewed articles, over 100 conference proceedings, book chapters and international abstracts, and holds 8 patents. He has edited the most recent and comprehensive textbook on PDT entitled *Advances in Photodynamic Therapy: Basic, Translational, and Clinical*. He has developed an interest in elucidating the basic molecular and cellular
mechanisms of LLLT, and for the past four years has chaired an annual conference at SPIE entitled “Mechanisms for Low-Level Light Therapy.” Dr. Hamblin may be contacted by e-mail at Hamblin@helix.mgh.harvard.edu.

Disclosure: Dr. Hamblin’s laboratory has received sponsored research support from Palomar Medical Technologies Inc, Laser Hair Therapy of North America, and Lexington International. Dr. Hamblin has received consulting fees from the last two companies and is on the scientific advisory board of Lexington International.

PRESENTATION 9: LIGHT MODULATES DNA, RNA, AND PROTEIN EXPRESSION IN THE NERVOUS SYSTEM
Juanita J. Anders, PhD
Professor, Department of Anatomy, Physiology, and Genetics, Uniformed Services University of the Health Sciences

Abstract
This presentation will focus on changes in mRNA and DNA expression in the nervous systems following injury and light therapy. The ability of light to alter the mRNA expression in progenitor cells will also be presented.

Biography
Dr. Juanita Anders is a professor of Anatomy, Physiology, and Genetics at the Uniformed Services University of the Health Sciences (USUHS). She also has a secondary appointment as professor of Neuroscience at USUHS. She received her PhD in Anatomy from the University of Maryland Medical School and specializes in peripheral and central nervous system injury and repair mechanisms. While at the National Institutes of Health in the Laboratory of Neuropathology and Neuroanatomical Sciences, National Institute of Neurological Disorders and Stroke (NINDS), she specialized in glial/neuronal interaction in normal and injured nervous tissue. Since joining USUHS, her research interests have expanded to the use of light as a noninvasive therapy for deep tissue injuries and the interaction of light with pluripotent cells. Her research on the use of light applied noninvasively for repair of spinal cord injury has received international attention. She is recognized as an expert in light therapy and has been invited to speak and chair sessions at numerous international laser conferences. Dr. Anders serves on the Executive Councils and Scientific Advisory Boards of several laser societies. She is also the Basic Sciences representative on the Board of ASLMS. She is the past president of the North American Association for Laser Therapy and a founding member of the International Academy of Laser Medicine and Surgery. She serves on the Editorial Boards of Photomedicine and Laser Surgery and Lasers in Surgery and Medicine and as a reviewer for several other journals. She has published more than 50 peer-reviewed articles. Dr. Anders may be contacted by e-mail at janders@ushus.mil.

Disclosure: Dr. Anders has no dual commitments as defined in the ALD Disclosure Policy. In the course of this presentation she will discuss the Thor Laser, an investigational device used to irradiate spinal cords.

PRESENTATION 10: LLLT-ACTIVATED TGF-BETA: A MOLECULAR MEDIATOR IN ORAL WOUND HEALING AND DENTINAL REPAIR
Praveen R. Arany, BDS, MDS
Harvard School of Dental Medicine

Abstract
The ability of laser light to modulate specific biological processes has been well documented but the precise molecular mechanisms mediating these photobiological interactions remain an area of intense investigation. This presentation will cover two aspects of laser biological interaction with emphasis on the molecular pathways involved in oral wound healing and dentinal tissue repair. We recently published the results of our clinical trial with 30 patients in an oral tooth-extraction wound healing model using a 904-nm GaAs laser (Oralaser 1010, Oralia, Konstanz, Germany), assessing healing parameters using routine histopathology and immunostaining (Arany PR, Nayak RS, Hallikerimath S, Limaye AM, Kale AD, Kondaiah P. Activation of latent TGF-beta1 by low-power laser in vitro correlates with increased TFG-beta1 levels in laser-enhanced wound healing. Wound Rep Regen 2007, 15(6):866-874). We observed a better organized healing response in laser-irradiated oral tissues that correlated with an increased expression of TGF-beta1 immediately after laser irradiation. We also demonstrated the ability of the low-power near-infrared laser irradiation to activate the latent TGF-beta complexes in vitro at varying fluences using an isoform-specific enzyme-linked immunosorbent assay (ELISA) and a reporter-based (p3TP-lux) assay system. I will present some of our latest data further characterizing the precise photomolecular mechanism affecting the latent TGF-beta activation process by LLLT. I have been studying the role of specific growth factors and physical niche in determining odontogenic differentiation. Interestingly, TGF-betas have been shown to be key regulators in dentin differentiation. I have been using a combination of scaffold approaches, morphogen cues, and stem cells to explore the role of low-level laser therapy (LLLT) in activating the latent TGF-beta complex and drive dentinal differentiation in vitro.
These experiments are directed toward addressing the rationale of LLLT as a clinical treatment modality in pulp capping and desensitization procedures with the hope that understanding the basic mechanisms will improve the efficacy of these treatments in clinical care. In summary, I will present evidence of a potential molecular mechanism for laser photobiomodulation in its ability to activate latent TGF-beta complexes.

**Biography**

Dr. Praveen Arany trained as a dentist and oral pathologist in India and did his postdoctoral fellowships in molecular and cell biology at the Indian Institute of Sciences, Bangalore and the National Cancer Institute, NIH, Bethesda. He is presently pursuing an interdisciplinary joint PhD-Residency program across various Harvard institutions including the Harvard School of Dental Medicine, Harvard Medical School, Harvard School of Engineering & Applied Sciences, and the Brigham and Women’s Hospital. His present research is focused on understanding the intricate signaling mechanisms involved in sensing and responding to external cues during development, wound healing, and regeneration as well as the loss of these regulated processes during carcinogenesis. Dr. Arany can be contacted by email at arany@fas.harvard.edu.

**Disclosure:** Dr. Arany has no dual commitments as defined in the ALD Disclosure Policy. In the course of this presentation, he will discuss the 904-nm laser, an investigational device used for oral wound healing.

**Presentation 11: Near-Infrared LED Photobiomodulation to Enhance Bone Density and Osteointegration**

Jerry Bouquot, DDS, MSD
Professor & Chair, Department of Diagnostic Sciences, University of Texas, Dental Branch at Houston

**Abstract**

Dental implants must be placed in healthy bone for successful osteointegration and stability. Low bone density (LBD) and ischamically damaged, desiccated bone both have a poor ability to remodel and are, therefore, contraindications for implants. Readily available diagnostic imaging devices, including dental radiographs, lack the ability to adequately identify such bone. QUS (through-transmission ultrasound) is specifically cleared by the FDA to safely identify LBD and dehydrated bone and has a very low (<3%) false positive rate.

Furthermore, near-infrared light-emitting diode (NIR-LED) “therapy” or photobiomodulation has been shown in cultured cells and animal models to stimulate bone healing and production. This presentation will summarize the results of a clinical investigation which used QUS to determine the efficacy of NIR-LED phototherapy to increase bone density and/or hydration of abnormal alveolar bone. It will also review the literature on NIR-LED use in healthy and diseased tissues, as well as the results of a very recent in vitro experiment evaluating the attachment of osteoblasts to titanium implant material with and without NIR-LED use.

In vivo investigation of jawbone osteoblastic proliferation and attachment to titanium implant material: Cells derived from human mandibular bone were exposed to NIR-LED at doses of 1 or 2 J/cm² and then seeded onto titanium discs. Nonexposed cultures served as controls. After 3 and 6 h, cells were stained and those attached to the titanium were counted via light microscope. Additionally, the effect of LED on cell proliferation was examined after 48, 72, and 96 h; cells were cultured on titanium specimens for 24 h and then exposed to LED for three consecutive days. Cell proliferation was determined by cell counts via light microscopy. Mean transit time (MTT) analyses were also performed to determine cellular attachment and proliferation.

Cellular attachment was significantly enhanced (p < 0.05) by NIR-LED irradiation at doses of 1 and 2 J/cm² after 3 and 6 h. The proliferation assays showed higher cell proliferation (p < 0.05) in irradiated groups at doses of 1 and 2 J/cm² after 72 and 96 h with agreement between cell counting and MTT analyses. Attachment and proliferation of human osteoblast-like cells cultured on titanium implant material appear to be significantly enhanced by NIR-LED irradiation, suggesting a future use for this technology in alveolar implants.
**Biography**

Dr. Jerry Bouquot is professor and chair of the Department of Diagnostic Sciences, University of Texas Dental Branch at Houston. He has been a chair in two different dental schools for a total of 23 years and is a diplomat and past president of the American Board of Oral & Maxillofacial Pathology. He has more than 2 decades of research experience in ischemic alveolar bone problems and his research was used to obtain FDA clearance for the first through-transmission ultrasound (QUS) device for dentistry. He and his co-investigators have also presented their research results relating to the use of LED photobiomodulation on bone density and osteoblastic activity at national and international scientific meetings. Dr. Bouquot may be contacted by email at jerry.bouquot@uth.tmc.edu.

**Disclosure:** Dr. Bouquot has no dual commitments as defined in the ALD Disclosure Policy. In the course of this presentation he will discuss the OsseoPulse laser, an investigational device used to deliver NIR-LED to the jaw.

**Presentation 12: FDA Physics Division’s Research on Light-Based Technology**

Ronald Waynant, PhD
Senior Optical Engineer, U.S. Food and Drug Administration, Rockville, Maryland

**Abstract**

This presentation will discuss FDA research into the mechanism of laser therapy over the last eight years including results with devices covering a wide wavelength range, the discovery of hydrogen peroxide as a major product when light interacts with cell cultures, and the measurement of hydrogen peroxide. This work will also touch on our belief that the bystander effect noted in radiobiology experiments also stems from a similar mechanism produced by typical radiobiology sources and our efforts to confirm this activity. We will also mention our thoughts of ways to extend our results in cell cultures to interactions in animals and humans perhaps leading to measurements of the status of our immune system.

**Biography and Disclosure**

Details are listed above.

**Closing: Open Forum Discussion**

“The Future and Where Do We Go From Here?”
Donald J. Coluzzi, DDS, Moderator

**Summary**

All of the presentations were well-received and each prompted some discussion. The closing session featured an interchange of thoughts about the FDA’s regulatory process particularly as it applies to marketing clearances. The ALD collected evaluations from some of the participants and all of the feedback was very positive for the program contents and the overall experience.
In his description of two clinical cases (37-38), Dr. Alfred Wyatt, Jr. utilizes an Er:YAG laser to assist with the removal of porcelain veneers. He indicates the procedure lies in the assumption that the laser energy is transmitted through the veneer and absorbed by the resin-based luting cement.

Few published reports exist concerning the use of erbium lasers for this application. Three related abstracts are shown below. Two private practitioners, Patrick Broome and Steven Spitz, independently report on their results when using an Er,Cr:YSGG laser to remove porcelain veneers. A research team led by Yuko Watanabe from the Nippon Dental University in Tokyo relates their experience on the effects of Er:YAG laser irradiation on a variety of restorative materials, including porcelain.

Central to the ability of erbium lasers to remove porcelain veneers is the extent to which the laser light is transmitted through the ceramic material. Most studies focusing on the translucency of or light transmission through dental porcelains have examined various conventional halogen curing lights typically operating in the range of approximately 400 to 500 nm, or light-emitting diode (LED) devices, to assess polymerization efficacy.1-8 The abstract of one such study is reproduced below. In this case, a group of investigators from the Federal University of Minas Gerais in Brazil used the incident light from two light cure units (Optilux models 401 and 403, Demetron/Kerr, Danbury, Conn.) in their study of light transmission through porcelain of varying thicknesses and shades. In another study, Broadbelt and colleagues1 noted a high degree of light scattering in dental porcelains, and that transmission increased with incident wavelength, through their investigated upper parameter of 700 nm. Further spectrophotometric analysis of the transmission of additional wavelengths of light through porcelain, and subsequent absorption into and debonding of the underlying luting composite, is warranted.

For U.S. readers, no laser has been cleared by the U.S. Food and Drug Administration for removal of porcelain veneers.

As always, clinicians are advised to review the specific indications for use of their lasers and to review their operator manuals for guidance on operating parameters before attempting similar techniques on their patients.

REFERENCES

Adhesive bonding lies at the core of aesthetic dentistry and involves various restorative materials that can be used to “mimic” nature. When the removal of a bonded porcelain restoration is necessary, a high-speed handpiece with a diamond bur has been the only option for clinicians to facilitate removal and reveal the remaining tooth structure. By using minimally invasive laser technology, however, the clinician may remove a bonded restoration without cutting it off by simply reversing the light- or dual-cure resin chemical reaction. Feldspathic and/or pressed ceramic restorations can be removed via an Er,Cr:YSGG laser (i.e., Waterlase MD, Biolase, Irvine, Calif.), which selectively interacts with water molecules in the adhesive resin and hybrid zone. Laser energy passes through porcelain glass unaffected and is absorbed by the water molecules present in the adhesive. Clinical observations indicate that the debonding occurs at the silane-resin interface since the denatured resin remains attached to the tooth structure and the restoration debonds without any residual resin attached to its inner surface. The water molecules are selectively excited, thus causing delamination of the restoration. Once bond failure occurs, the restoration can be removed – often in one piece – and the original preparation may be accessed without underlying tooth structure removal.

The practice of prosthodontics takes all concepts of dentistry and integrates effective comprehensive treatment planning. The practice will necessarily include a wide variety of patients seeking a diverse range of care. These include individuals who are highly fearful of dentistry and have long-term neglected care and those who have complex medical histories and require more specialized, advanced procedures. Some also have phobias and/or allergies to anesthetics. Lasers have become an integral part of treatment for these patients. Procedures such as class I through V restorations, crown and veneer preparations, gingival contouring, including surgical placement, can be performed comfortably and effectively, often with little or no anestheisa…When removing bonded porcelain restorations in the past, a high-speed drill with a diamond bur was the only option. With laser technology, the restoration can now be removed without cutting it off. The laser energy passes through porcelain glass unaffected and is absorbed by the water molecules present in the adhesive. It appears that this debonding occurs at the silane-resin interface because the underlying tooth structure appears to be unaffected. The technique takes approximately 5 to 30 seconds for feldspathic, and 2 seconds to 2 minutes for pressed, as the time will vary upon the thickness of the restoration. The restoration can often be removed intact, which can aid the lab technician on color matching. [The described case] shows a fractured restoration on the lower right lateral incisor. Beginning at the gingival aspect, a 2780-nm Er,Cr:YSGG laser, Waterlase, Biolase Technology, Irvine, Calif., at 4 W, 20% water and 40% air, was used to initiate removal, and the process proceeds quickly, with minimal removal of any tooth structure.
RESEARCH ABSTRACTS

THE EFFECTS OF THE ER:YAG LASER IRRADIATION ON THE NEW TYPE RESTORATIVE MATERIALS

Yuko Watanabe, Toru Eguro, Toru Maeda, Hisayoshi Tanaka
The Nippon Dental University School of Dentistry at Tokyo
Shigaku (Odontology) 1999;87(3):329-339

The Er:YAG laser has been used to treat dental decay. The purpose of this study was to observe the morphological surface changes of new types of tooth-colored restorative materials irradiated with Er:YAG laser and to analyze the changes using electron probe microanalysis (EPMA). The specimens were prepared from 5 tooth-colored restorative materials (porcelain, castable ceramics, hybrid ceramics, ceromer material, and polymer glass). Each specimen was irradiated with a fine water mist under the following conditions: energy, 300 mJ; pulse frequency, 1 Hz; focal distance, 12 mm; and total pulse, 1 shot/3 shot. The surfaces of the specimens were examined and analyzed by EPMA. The width and depth of the craters produced on the surface by Er:YAG laser irradiation were measured with a measuring scope. The data were analyzed by ANOVA and Tukey’s q-test. The results were as follows: 1. Porcelain and castable ceramics were not affected by the Er:YAG laser irradiation. 2. The Er:YAG laser irradiation was able to ablate the hybrid ceramics, ceromer material and polymer glass. These surfaces had a crater form. The degree of ablation was significantly different among these three materials. 3. EPMA observation revealed that the Er:YAG laser irradiation caused filler particles of hybrid ceramics, ceromer material and polymer glass to protrude from the surface of the craters.

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LIGHT TRANSMISSION THROUGH PORCELAIN

Rogéli T.R.C. Peixoto, Vanessa Maria F. Paulinelli, Herbert H. Sander, Marcos D. Lanza,
Luiz Alberto Cury, Luiz Thadeu A. Poletto
Federal University of Minas Gerais, Belo Horizonte, Brazil
Dent Mater 2007;23(11):1363-1368

Objective. This study evaluates the effect of shade and thickness of porcelain in light transmission. Methods. One hundred and twenty-eight disks of Duceram® porcelain were made to combine four different thicknesses (1.5; 2.0; 3.0; 4.0 mm) and eight shades (A1; A4; B3; B4; C1; C4; D2; D4). A digital power meter (Newport Optical Power Meter®) was used to measure light transmission. The porcelain transmission coefficient was calculated using Lambert-Beer law, 

\[ t_c = C e^{-\alpha d} \]

where \( t_c \) is the transmission coefficient, \( C \) the contribution factor of the reflection coefficient, \( e \) a constant, \( \alpha \) the absorption coefficient and \( d \) is the sample thickness. Results. The transmission coefficients did not vary statistically in relation to the two visible light-curing units studied. From all the samples, the colors A1 and D2, thickness 1.5 mm, presented the highest percentages of transmission (8%) and the shades, A4, B4 and C4, thickness 4 mm, the lowest (0.5%). The relationship between the Naperian logarithm of the transmission coefficient and the samples thickness followed the Lambert-Beer law. The linear adjustment of the experimental points of the two variables, showed the absorption coefficient (\( \alpha \)) and the constant value related to the reflection (\( C \)) of each porcelain shade. The reflection coefficient values of all shades did not vary statistically among themselves. Significance. For most shades there was a significant decrease in light transmission as the sample porcelain thickness increased. For the same thickness most shades presented statistical difference between the transmission coefficients. However, the larger the thickness, the higher the number of shades which, statistically, showed no difference.

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Dr. Arthur Levy presents a protocol for the adjunctive use of a soft tissue laser for treatment of periodontal disease (21-26). To complement his perspective, readers may wish to examine the following articles related to laser treatment of periodontal disease that have appeared in previous issues of *Wavelengths* and the *Journal*.

The Journal of Laser Dentistry’s Continuing Dental Education Program offers readers an opportunity to earn one CE self-instructional credit for one of the articles in this issue. Read the specified article and then select the most correct answer to each of the questions below. If you correctly answer 7 of the 10 questions on the test (for a score of 70%), you earn one credit hour. The answer form must be completed as directed in the instructions; otherwise, it will not be processed.

This program is developed by representatives of the Academy of Laser Dentistry’s Science and Research committee and is provided as a benefit to ALD members at no additional charge. Nonmembers are also eligible to participate for a $20 administrative fee per issue. Answers to this exercise will be published in a future issue.

Please photocopy and legibly complete the registration form as well as the answer sheet and evaluation form on page 64 and mail it (along with the quarterly $20 administrative fee if you are not an ALD member) to:

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Payment may be by check drawn on a U.S. bank, money order, or VISA or MasterCard. Please keep a copy of your answers for your records. ALD will not return your answer sheet. Answers to the test will be published in a future issue of the Journal. ALD will send an indication of the status of your CE credit within 90 days of the published due date (July 31, 2009).

Your test is graded by representatives of the Academy of Laser Dentistry, an ADA CERP recognized provider.

You will be notified by mail of your test score(s) and the number of credits awarded. You must then forward the information to your state dental board or agency for licensure purposes. Individuals who score less than 70% will receive a letter.

Answers to these tests are due on or before July 31, 2009.

Please call the Academy of Laser Dentistry (954) 346-3776 if you have any questions about this program.
Educational Objectives

Upon successful completion of this module, you will be able to:

- Specify the major photobiological effect of surgical lasers used in dentistry, and describe the main factors that influence this effect.
- Define photobiomodulation and specify how such effects are produced by lasers.
- Define the terms vaporization, ablation, coagulation, carbonization, conduction, convection, and radiation.
- Specify at which temperatures pathogen deactivation, coagulation, vaporization, and carbonization occur.
- Identify which dental laser wavelength is most strongly absorbed by water.
- Describe how thermal laser-tissue interaction may be maximized.

Test Questions

1. The type of photobiological effect produced by a laser is primarily dependent on the:
   a. laser's delivery system and handpiece tip
   b. laser's power density and duration of exposure
   c. water content of the target tissue
   d. degree of fluorescence of the target tissue

2. The predominant photobiological effect of currently available dental surgical lasers is:
   a. photodisruption
   b. photoablative
   c. plasma-induced ablation
   d. thermal

3. Photobiomodulation effects are produced by:
   a. power densities in excess of 1,000 Watts per square centimeter
   b. low energy levels and low thermal input
   c. exposure durations less than one millisecond
   d. tissue temperatures in excess of 100 degrees Celsius

4. Ablation is defined as:
   a. removal of a segment of tissue by a thermal interaction
   b. nonthermal disruption of the tissue
   c. coagulation of proteins
   d. biostimulation of connective tissue

5. Vaporization occurs at which temperature?
   a. 50 degrees Celsius
   b. 60 degrees Celsius
   c. 100 degrees Celsius
   d. 200 degrees Celsius

6. Coagulation of soft tissue occurs at which temperature?
   a. 50 degrees Celsius
   b. 60 degrees Celsius
   c. 100 degrees Celsius
   d. 200 degrees Celsius

7. Conduction is:
   a. transfer of heat by radiation
   b. removal of tissue by photodisruption
   c. absorption of heat during noncontact procedures
   d. transfer of heat by direct molecular collision

8. Radiation is:
   a. transfer of heat by direct conduction
   b. utilization of the heat of the laser beam
   c. transfer of energy by electromagnetic waves
   d. reflectance of laser energy from the target tissue

9. In order to maximize the thermal laser-tissue interaction, which of the following is required?
   a. the laser wavelength should be closely matched to the tissue’s chromophore(s)
   b. the laser must be used in a continuous-wave mode
   c. only far-infrared laser wavelengths should be used
   d. the laser energy should be totally transmitted through the tissue

10. Of the currently available dental laser wavelengths listed below, the maximum water absorption occurs with which of the following?
    a. 810 nm
    b. 980 nm
    c. 2,940 nm
    d. 10,600 nm
CONTINUING EDUCATION CREDIT REGISTRATION FORM

Please print or type clearly. The certificate will be issued from the information given.

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ANSWER SHEET FOR TEST 1711

Laser-Tissue Interaction I
Michael Swick, DMD

Subject Code: 497

Place an X in the box corresponding to the answer you believe is most correct.

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Program Evaluation — Test 1711
Please evaluate this article.

Poor = 1 to Excellent = 5

Clarity of objectives ___

Usefulness of the content ___

Benefit to your clinical practice ___

Quality of the manuscript ___

Usefulness of the references ___

Quality of the illustrations ___

Relevance of the illustrations ___

Clarity of the questions ___

Relevance of the questions ___

The article presented new information ___

Program achieved its educational objectives ___

How many minutes did it take you to read the article and complete the test? ___

Please list future CE topic preferences:

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ANSWERS TO PREVIOUS CE PROGRAMS

ACADEMY OF LASER DENTISTRY • SELF-INSTRUCTION PROGRAM NO. 1621
Subject Code: 250
Clinical Considerations for the Use of Er:YAG Lasers in Restorative Dentistry
Giuseppe Iaria, Dr. Prof. Med. Dent., Steven P.A. Parker, BDS, LDS RCS, MGDP
J Laser Dent 2008;16(2)

Test questions with correct answers underlined

1. The use of laser energy in the ablation of dental hard tissue is an example of:
   a. photochemical interaction
   b. photothermal interaction
   c. photobiomodulation
   d. photogenic interaction

2. Several factors contribute to the efficient erbium laser ablation of dental hard tissue. Among these are the:
   a. laser’s delivery system
   b. power density at the ablation site
   c. type of anesthesia used on the patient
   d. amount of preconditioning of the laser tip

3. The principal laser wavelengths used in tooth preparation are Er:YAG and Er,Cr:YSGG. Their respective wavelengths are:
   a. 2,100 nm and 2,780 nm
   b. 2,100 nm and 2,940 nm
   c. 2,780 nm and 2,940 nm
   d. 2,940 nm and 9,600 nm

4. The erbium laser wavelengths have a:
   a. high absorption by water
   b. low absorption by water
   c. very high absorption by hydroxyapatite
   d. very low absorption by collagen

5. The surface of dentin after exposure to either Er:YAG or Er,Cr:YSGG laser irradiation has the following characteristics:
   a. a smear layer and closed tubules
   b. a smear layer and open tubules
   c. absence of a smear layer
   d. presence of carbonization

6. A co-axial water spray during erbium laser preparation of enamel and dentin is necessary because the spray:
   a. serves to aim the laser beam at the target
   b. cools the laser tip
   c. aids in desensitizing the tooth structure
   d. helps to disperse debris and ablation products

7. Erbium laser irradiation of enamel and dentin results in a micro-cavitated surface. This surface:
   a. should be desensitized to avoid pulpal damage
   b. is ideal for bonding composite resin
   c. requires additional acid-etch techniques to minimize early marginal breakdown of the composite restoration
   d. should be protected with a cavity liner prior to restoration

8. Each of the following is a safety consideration when using erbium laser wavelengths EXCEPT one. Which one is this EXCEPTION?
   a. wavelength- and device-specific protection glasses for the doctor, the assistant, and patient to prevent eye damage
   b. appropriate face-masks to avoid plume aspiration
   c. high-speed evacuation of plume and debris to remove potentially harmful combustion byproducts
   d. encasement of the laser tip in a wavelength-specific shield to minimize unwanted beam diversion

9. Which of the following statements is true? Erbium laser energy:
   a. has greater absorption in demineralized tooth structure than in healthy tooth structure
   b. is so efficiently absorbed that no debris accumulates in a deep preparation
   c. has greater absorption in healthy tooth structure than in demineralized tooth structure
   d. does not cause any thermal rise in the target tissue

10. Studies of the pulpal temperature rise when using erbium lasers confirm the following:
    a. temperature rise is rapid with each pulse and care should be taken to avoid damage
    b. pulpal temperature rise is within 5 degrees Celsius above normal
    c. pulpal temperature rise is approximately the same as with an air turbine
    d. erbium laser wavelengths induce photobiomodulation which keeps the temperature rise within normal limits

Answer Sheet for Test 1621

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Test questions with correct answers underlined

1. Which of the following statements is true? Peri-implantitis:
   a. manifests as an inflammation of the structures surrounding an implant fixture
   b. is a disease of soft tissue destruction only
   c. has clinical signs similar to a carious lesion
   d. cannot be treated with a laser

2. One of the major factors contributing to peri-implantitis is the:
   a. design and shape of the implant fixture
   b. specific tooth that is being replaced by the implant
   c. amount of bacterial exposure to the implant
   d. length of time that the implant has been allowed to osseo-integrate

3. The development of peri-implantitis can occur because of:
   a. the quantity of bone surrounding the area where the implant is to be placed
   b. the initial depth of the osteotomy
   c. the thermal trauma to the periodontium during the osteotomy
   d. a postoperative complication

4. Clinical signs of peri-implantitis include:
   a. marginal discrepancy of the restoration
   b. bleeding or purulence from the gingival tissue
   c. loosening of the restoration from the abutment
   d. fracture of the mechanical connection between the restoration and the abutment

5. Which of the following is a therapeutic treatment of peri-implantitis?
   a. removal of the implant fixture and restoration
   b. occlusal adjustment of the restoration
   c. removal of the granulation tissue with plastic curettes
   d. supragingival prophylaxis with pumice

6. The Er:YAG laser can be used for the treatment of peri-implantitis because this device:
   a. is highly absorbed by the metallic surface of the implant fixture
   b. can reshape the body of the implant fixture
   c. produces very high temperatures in the osseous tissue
   d. can vaporize the existing inflammatory granulation tissue

7. The Er:YAG laser can be used for dental osseous surgical procedures because it:
   a. instantly provides coagulation of the osseous tissue
   b. will remove only healthy osseous tissue and not the inflammatory material
   c. is effective in removing necrotic and healthy osseous tissue
   d. will regenerate needed osseous tissue

8. The Er:YAG laser can be used directly on the implant surface because it:
   a. has no damaging effect on the implant screw areas at low energy settings
   b. can be used to remove some of the screw threads
   c. will recrystallize the metallic surface of the implant to harden it
   d. will not disturb the biofilm that adheres to the implant

9. According to the peri-implantitis treatment plan described in the article, the Er:YAG laser will be used for:
   a. carving the occlusal surface of the implant restoration
   b. making a pilot hole for the osteotomy
   c. preparing the donor gingival graft site
   d. ablatting the soft and hard tissue in the periodontal defect

10. According to the peri-implantitis treatment sequence described in this article:
    a. a free gingival graft was placed over ablated soft tissue
    b. a xenograft bone substitute material was placed into the cleaned defect
    c. the soft granulation tissue was removed with hand instruments
    d. the implant fixture was removed

Answer Sheet for Test 1622

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Test questions with correct answers underlined

1. Lasers are an effective alternative for treating pulps in pediatric teeth without the need to:
   a. use local anesthetics
   b. use tooth isolation
   c. introduce chemicals
   d. sedate the patient

2. A pulpotomy is defined as:
   a. the removal of the coronal pulp of a tooth
   b. the removal of very deep dentinal caries
   c. a root canal procedure for pulp tissue that is irreversibly infected or necrotic due to caries or trauma
   d. placement of calcium hydroxide paste on the healthy dentin

3. A concern when using formocresol for pulpotomy treatment of primary teeth is that:
   a. formocresol may be absorbed and distributed throughout the child's body within minutes of its use at the pulpotomy site
   b. the child may have extreme pain immediately after the tooth is treated
   c. the child may complain of a burning sensation after the tooth is treated
   d. formocresol may get on and discolor the child's skin if the child moves

4. When a laser is utilized to perform a pulpotomy, which of the following statements applies?
   a. the laser should not be used on children under the age of one year
   b. the laser should not be used on permanent teeth
   c. the laser treatment’s success is similar to that achieved with chemical pulp therapy
   d. a carbon dioxide laser is the preferred wavelength for a laser pulp treatment

5. Which of the following is true for Er:YAG laser pulpotomy treatment? The laser:
   a. should be used with the tip placed 5 mm from the pulp chamber
   b. can be utilized for a pulpotomy as an alternative to electrosurgical therapy
   c. is always used to remove tooth structure for access to the pulp chamber
   d. is always used without any local anesthetic

6. When the Er:YAG laser is used for pulp therapy, which of the following applies?
   a. only the child patient requires laser safety glasses
   b. everyone within the operating area is required to use laser safety glasses
   c. no one in the operating area requires laser safety glasses, since the Er:YAG laser is harmless to the eyes
   d. only the dentist is required to use laser glasses since the child’s mouth is so small the laser beam stays within the child's oral cavity

7. A successful pulpotomy on a primary tooth should last:
   a. one year
   b. five years
   c. ten years
   d. until the permanent tooth normally erupts

8. As indicated in the published case study, successful pulpotomy therapy using the Er:YAG laser requires a power setting of approximately:
   a. 4 Watts
   b. 6 Watts
   c. 0.75 Watt
   d. 1.65 Watts

9. Which of following is required when using the Er:YAG laser for a pulpotomy on a pediatric patient?
   a. high-volume evacuation
   b. premedication for the patient
   c. use of loupes or a microscope
   d. presence of the patient’s parent in the operatory

10. The Er:YAG laser can be used to treat:
    a. only posterior primary and permanent teeth
    b. only anterior primary teeth
    c. only vital teeth
    d. both vital and non vital primary teeth

Answer Sheet for Test 1623

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Test questions with correct answers underlined

1. The currently available laser wavelength(s) that have clinical indications for use in performing osseous surgery is (are):
   a. all diodes
   b. Nd:YAG
   c. carbon dioxide
   d. Er,Cr:YSGG and Er:YAG

2. The wavelengths utilized for osseous surgery are absorbed by the chromophores in bone, including:
   a. hemoglobin and oxyhemoglobin
   b. water and the hydroxyl group of hydroxyapatite
   c. phosphate and nitrate groups
   d. melanin and xanthophyll

3. When an osteotomy for the placement of an implant fixture is performed with a laser, which of the following statements is true?
   a. the laser has an advantage because it can much more rapidly prepare the site than size-matched burs
   b. the water spray used for cooling the tissue is easily directed into even the deepest preparations with conventional tips
   c. the end-cutting laser beam does not allow for a measured development of a three-dimensional preparation
   d. studies have shown significant disrupted healing of laser-prepared osteotomies compared to the control group

4. To avoid damage to osseous tissue with a laser, the maximum temperature to which bone should be raised during osseous surgery is:
   a. 47 degrees Celsius
   b. 42 degrees Celsius
   c. 80 degrees Celsius
   d. 57 degrees Celsius

5. The application of laser energy on the metal implant should be accomplished under which of the following considerations:
   a. Use a laser with a power density of several thousand Watts per pulse
   b. Use a laser with a high peak power per pulse without a water spray
   c. Use a laser in continuous-wave mode with an average power of approximately 1.0 W
   d. Use a laser that causes detectable disruption of the coated implant surface

6. Which of the following statements applies to second-stage uncovering of an implant fixture? The procedure:
   a. should not be performed with a laser because of the laser's potential to harm the fixture
   b. can be performed with any commercially available laser wavelength
   c. should not be performed with a laser because of the laser's potential to damage the periodontium
   d. can be performed only with fiber-delivered lasers with water spray

7. According to the author, second-stage uncovering of the implant with a laser:
   a. can be performed without regard to the thickness and vascularity of the soft tissue
   b. should be performed at a starting average power of 4-5 Watts
   c. starts with removing a small cone of tissue until near-contact with the implant is made
   d. should produce rapid buildup of carbonized material on the soft tissue surface and the tip of the laser

8. Which of the following was demonstrated in the article's accompanying clinical case examples of second-stage uncovering of the implant fixture?
   a. the choice of laser wavelength is irrelevant, as long as the proper parameters are utilized
   b. the laser clearly damaged the periodontium
   c. excessive soft tissue must not be removed with a laser
   d. a laser cannot be used to contour the gingival tissue after uncovering the implant

9. The generally accepted definition of the term peri-implantitis is:
   a. the acute inflammation of only the marginal gingival tissue adjacent to a functional implant
   b. inflammatory reactions with loss of supporting bone in tissues surrounding a functional implant
   c. the loosening of the implant abutment
   d. disintegration of the restorative material on the abutment crown

10. In the treatment of peri-implantitis, which of the following is true?
    a. the presence of biofilm on the implant surface causes no concern
    b. removal of granulation tissue is not recommended by the author
    c. occlusal loading is never analyzed
    d. pathogen reduction is a primary step

Answer Sheet for Test 1631

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