Lasers in Dentistry

In this issue, we feature peer-reviewed submissions of four presenters from our 11th Annual Conference in Indian Wells, California. The first three are generated from the research arena and the final article shows a clinical perspective.

We are using a new format for three of the authors. Starting with their original abstract text, they each have added additional material, figures and legends.

- Dr. Akira Aoki synthesizes a just-published clinical study by him and his colleagues that demonstrates how an erbium:YAG laser can safely and effectively perform osseous periodontal surgery.
- Dr. Emil Litvak explains his work on developing a new scanning technology for delivering erbium:YAG laser energy to tissue with increased ablative efficiency. He provides his in vitro results for his patented process.
- Dr. Linda Otis and her colleagues describe a study using Optical Coherence Tomography to measure blood flow of the submucosal oral labial tissue. The results show that the technique could be applied to help diagnosis of active inflammatory periodontal disease.
- Ms. Paula Casper, a registered dental hygienist, presents a three-year clinical case study of her treatment of periodontal disease.

Our readers should be able to appreciate how continued study and application of laser energy can benefit our dental patients.

Research Studies

Clinical Evaluation of Periodontal Osseous Surgery with an Er:YAG Laser
Akira Aoki, DDS, PhD; Hisashi Watanabe, DDS, PhD; Fumihiko Akiyama, DDS; Shigeru Shoji, DDS, PhD; Hiroshi Horiuchi, DDS, PhD; Isao Ishikawa, DDS, PhD Japan

Novel Technology for Effective Tissue Ablation Based on the Er:YAG Dental Laser
Emil Litvak, DMD - Yahud, Israel

Optical Coherence Tomography of Oral Soft Tissues
Linda L Otis, DDS - Philadelphia, PA Daqing Piao, PhD - Hanover, NH Quing Zhu, PhD - Storrs, CT

Advanced Proficiency Case Study

Peaks and Valleys: A Three-Year Case Study Examining the Use of Diode Laser-Assisted Periodontal Therapy
Paula Jo Casper, RDH, BLS - New Castle, CO

2004 Source Conference Sessions

Now Available on Videotape and DVD!

Couldn’t go to Indian Wells? Or did you go and now want a videotape or DVD of the proceedings for reference?

Videotapes and DVDs are now available by contacting Joyco MultiMedia, LLC at (303) 421-0093, fax (303) 403-9112, or www.joycomultimedia.com.

Videos are also available from past ALD conferences.
Clinical Evaluation of Periodontal Osseous Surgery with an Er:YAG Laser

Akira Aoki, DDS, PhD (1); Hisashi Watanabe, DDS, PhD (1); Fumihiko Akiyama, DDS (1); Shigeru Shoji, DDS, PhD (2); Hiroshi Horuchi, DDS, PhD (3); Isao Ishikawa, DDS, PhD (1)

(1) Section of Periodontology, Department of Hard Tissue Engineering, Graduate School, Tokyo Medical and Dental University, Tokyo, Japan
(2) Department of Endodontics and Periodontics, Graduate School, Tohoku University, Sendai, Japan
(3) Professor Emeritus of Tohoku University, Sendai, Japan (3)

Dr. Aoki received his DDS degree from Tokyo Medical and Dental University (TMDU), Japan in 1989, and was a clinical resident from 1989 to 1991 and a clinical fellow from 1991 to 1996 in the Department of Periodontology, TMDU. He was awarded his PhD degree in 1996 and has been a Research Associate since 1996. In 2001 Dr. Aoki received the T.H. Mainman Award for excellence in dental laser research from the Academy of Laser Dentistry. In 2003 to 2004, he was a visiting assistant professor in the Department of Preventive and Restorative Dental Sciences, University of California, San Francisco, California. Dr. Aoki may be reached via e-mail at aoperi@tmd.ac.jp.

Disclosure: Dr. Aoki has no affiliation with any commercial organizations relevant to his presentation.

Introduction

Recently, the Er:YAG laser has been developed for use in dentistry and has more excellent characteristics favorable for periodontics than previous laser systems.1,2 Until now, the Er:YAG laser has been studied for calculus removal and bactericidal action, and clinically applied for calculus removal and soft tissue surgery and periodontal pocket treatment, and its potential for osseous surgery has also been reported.3,4 Thus, as it is capable of ablation in both soft and hard tissues, the Er:YAG laser could be applied during flap surgery involving bone tissue management as well as soft tissue debridement.

Design of Clinical Case Study

In the present study, we applied an Er:YAG laser (Prototype of Ervin AdvErLTM, Morita Mfg. Corp., Kyoto, Japan) for osteoplasty during flap surgery to recontour the irregular bone morphology resulting from periodontitis, and evaluated the clinical safety and usefulness of the procedure as well as the subsequent wound healing.

Thirty-one patients, 12 males and 19 females, aged 20-73 years (51.8 years on average) who required osteoplasty during flap surgery were treated by means of the Er:YAG laser. The laser irradiation was performed using a contact tip at an actual energy output of 28-104 mJ/pulse (73.3 mJ/pulse on average) and 10 Hz with saline water spray.

Clinical parameters such as pain, redness, swelling, and wound healing of the gingiva were evaluated before, immediately after, 1 week and 3 months after surgery. In addition, degree of the patient’s subjective discomfort during laser irradiation, ability of bone ablation, and features of the treated bone surface were examined. X-ray examination was conducted before and 3 months after surgery.

Results

The Er:YAG laser effectively ablated bone tissue without major visible thermal damages on the treated bone surface. In 30 out of 31 cases, osteoplasty was adequately performed with the laser, confirming its bone ablation ability. Only a few patients complained of slight discomfort during ablation, but most patients did not experience any discomfort due to unpleasant sound, smell or vibration. Wound healing of the treated sites progressed uneventfully without any systemic and local complications or side effects during the study period. X-ray examination showed no negative effects on the bone tissue after laser treatment. Figure 1 shows a representative case of the bone surgery using the Er:YAG laser.

Conclusion

Results of this study indicate that the Er:YAG laser can be used safely and effectively for osseous surgery in periodontal therapy.

References


A known problem with ablation of hard tissues is that the ablation process saturates after few tens of pulses. This fact is explained\(^*\) by excessive heating of the tissue under the ablated region, which causes evaporation of water from the tissue. This presentation describes a new application based on the Er:YAG (Fidelis Er, Fotona d.d., Ljubljana, Slovenia) dental laser that incorporates a patented Fast Scanning Technology (FST). In the present work, both the physical basics of FST and preliminary in vitro results are presented. FST is based on effective utilization of a pulsed Er:YAG laser with energies in the range of 500 mJ to a few Joules and variable pulse width combined with faster scanning of a treated tissue. The ablation dynamics variations along the pulse duration – including laser-induced transparency of water contained within hydroxyapatite, underlying tissue desiccation, and debris screening – strongly degrade the ablation efficiency of a laser pulse, as well as decrease the efficiency of a series of pulses. Fast Scanning Technology efficiently eliminates the effects of laser-induced transparency and debris screening, and significantly decreases tissue desiccation, thus improving the ablation efficiency and enabling the removal of large hard tissue areas within very short time periods. Effective algorithms controlling the scanning parameters allow the removal of tissue with a precise arbitrary shape and a precise depth that can vary along the removed area. The abilities of FST are demonstrated in vitro using extracted human teeth.

(Note: The editors asked questions of Dr. Litvak for elaboration of his research and possible clinical applications. The queries and answers follow.)

**JALD:** In Figure 2a you show and describe a graph with several pulse durations up to 400 microseconds, and then in the explanation of Figure 2b you speak of pulse durations of 1-2 milliseconds. Could you explain how the two relate since there is up to a ten-fold difference in those pulse durations?

**Dr. Litvak:** Figure 2a shows the penetration depth of a 400-µsec pulse at various time points during the pulse. This is a typical pulse duration of a free-running Er:YAG laser. Figure 2b shows the physical principle of FST. The typical pulse duration required for FST is a few milliseconds (ms). As seen in Figure 2a, the penetration depth becomes huge as the time from the beginning of the pulse evolves. This makes the ablation process totally inefficient toward the end of the pulse.

The FST comes to resolve this obstacle and to improve the ablation efficiency by allowing the laser to irradiate every point of the surface about tens of microseconds only, while the penetration depth is still small and the ablation efficiency high, as seen in Figure 2a. Figure 2b shows how this is accomplished by scanning the surface during the laser pulse. While scanning, the pulse duration is defined by the scan length and the time (tens of microseconds) that every point is irradiated. The longer the scan length, the longer the pulse, and vice versa. For example, a 1 ms pulse scanned over 5 mm has exactly the same ablation effect as a 2 ms pulse scanned over 10 mm (while keeping the laser peak power constant).

**JALD:** Your original abstract mentions energies of 500 mJ up to a few Joules and yet, as clinicians, we are not able to produce those levels of energy at our handpiece tips. Is this an experimental device, and if so, can you relate your findings to currently available devices with far less energy output?

**Dr. Litvak:** Commercially available Fotona lasers easily emit up to 1 Joule energy. Our device is a special handpiece equipped with FST implementation that uses a modified Fotona Laser. The trend in Er:YAG laser development is increasing penetration depth of a 400-µsec pulse at various time points during the pulse. This is a typical pulse duration of a free-running Er:YAG laser. Figure 2b shows the physical principle of FST. The typical pulse duration required for FST is a few milliseconds (ms). As seen in Figure 2a, the penetration depth becomes huge as the time from the beginning of the pulse evolves. This makes the ablation process totally inefficient toward the end of the pulse.

The FST comes to resolve this obstacle and to improve the ablation efficiency by allowing the laser to irradiate every point of the surface about tens of microseconds only, while the penetration depth is still small and the ablation efficiency high, as seen in Figure 2a. Figure 2b shows how this is accomplished by scanning the surface during the laser pulse. While scanning, the pulse duration is defined by the scan length and the time (tens of microseconds) that every point is irradiated. The longer the scan length, the longer the pulse, and vice versa. For example, a 1 ms pulse scanned over 5 mm has exactly the same ablation effect as a 2 ms pulse scanned over 10 mm (while keeping the laser peak power constant).

**JALD:** Further about energy levels, your Figure 2 shows an energy of 1000 mJ or 1 Joule. Is this your ideal energy for FST?

**Dr. Litvak:** Yes, that is indeed a typical parameter for FST; however, further optimization of the application is possible and we are currently studying those issues.

**JALD:** In our current clinical application, most devices have a few pulse rates; for example, from 3 to 30 Hz. It appears that you talk about a single pulse and then you mention subsequent pulses. How would the repetition rate affect your data? Would more Hertz accentuate the ablation inefficiency or minimize it?

**Dr. Litvak:** The major effect of the subsequent pulses is to evaporate water from the underlying tissues by the heat that penetrates deeper into the tooth (the water dissipation effect). This effect accentuates the ablation inefficiency if the laser is operated at a high energy level. However, when the energy level is low, the accumulated heating effect becomes significant and the ablation efficiency improves as the repetition rate increases. The optimal repetition rate depends on the laser energy level.

*References*

Figure 2a: Model Calculation
Laser penetration profile at various times from the beginning of the pulse. The spot diameter is 0.3 mm and the pulse energy is 1000 mJ. As expected, in the beginning of the pulse the laser is absorbed within the first 150 microns of the tissue. As time evolves, the amount of absorbed energy within the tissue increases and as a consequence the absorption coefficient decreases. This causes an increase in the laser penetration depth, clearly seen in the figure. At the end of the pulse, the laser energy is absorbed within 1.5 mm of the tissue. As the penetration depth increases, the amount of energy absorbed within a given material slice decreases, and as a consequence the ablation efficiency decreases. This demonstrates that the laser pulse effectiveness is determined mostly during the characteristic time $t$ and the subsequent energy in the pulse has a significantly less effect on the ablation and is mostly concentrated on the dehydration and heating of the underlying tissue.

Figure 2b: The Concept and Demonstration of Fast Scanning Technology
A relatively long laser pulse (1-2 milliseconds) is used. It is easier to achieve higher energies with longer pulses than with shorter ones because of technological reasons. The laser beam scans fast compared to the laser pulse time on the tissue, as shown by the pink spots. When the laser irradiation reaches the innermost red spot, the debris ejection (delayed by $t=150$ µsec) starts from the point shown by the yellow spot. This way each point is irradiated during the time period of $t$ and the laser energy application is most effective.

Figure 1a-c: Photographs of debris ejection from an extracted tooth 50, 250 and 500 microseconds (µsec) after the beginning of the laser pulse. The photographs were taken with a short exposure time (10 µsec) in synchronization with the laser pulse.

Figure 1d: The laser pulse intensity used in the experiment (the blue line) is shown. The red line with markers shows the amount of debris ejected as a function of time during the laser pulse. It should be noted that the debris ejection continues for about 300 µsec after the laser pulse ends. The decay of the debris ejection was analyzed with the exponential decay function, and the result was a typical time of 150 µsec. This amount of time is consistent with the normal processes involved in ablation.

Note that the debris ejection delay after the pulse begins is also on order of magnitude of $t$. This time can be used as a measure of short and long laser pulses. Pulses below $t$ are considered short, since no mechanical changes in the tissue appear during the deposition of the laser energy. Pulses greater than $t$ are considered long, since mechanical changes in the tissue appear during the laser irradiation.
Optical Coherence Tomography of Oral Soft Tissues

Linda L Otis, DDS, Associate Professor, The University of Pennsylvania School of Dental Medicine, lotis@pobox.upenn.edu
Daqing Piao, PhD, Research Associate, Thayer School of Engineering, Dartmouth College Daqing.Piao@dartmouth.edu
Quing Zhu, PhD, Associate Professor, University of Connecticut, Electrical and Computer Engineering, Zhu@ engr.uconn.edu

Dr. Otis is the Director of Oral and Maxillofacial Radiology at the University of Pennsylvania School of Dental Medicine. She has pioneered the application of OCT to dental medicine.

Disclosure: Dr. Otis has no affiliation with any commercial organizations relevant to this presentation.

Introduction

Optical coherence tomography (OCT) is a noninvasive optical technique for high resolution imaging of biological tissues. When applied to dental structures, OCT simultaneously images the teeth and periodontal tissues in cross-section without exposing patients to ionizing radiation. A functional imaging capacity can be obtained by integrating Doppler tomography and standard OCT, permitting both precise localization of vessels within oral tissues and the measurement of blood flow velocity. Functional imaging of the microcirculation of oral tissues would aid the diagnostic assessment of numerous oral disorders and provide important information for surgical treatment planning.

Materials and Methods

A prototype Doppler OCT system was constructed that detected phase-sensitive interference between light reflected from the sample and a scanning reference mirror. To determine the accuracy of this system to measure flow velocity, a colloid solution was passed through Tygon tubing at a fixed velocity. The accuracy of our prototype to measure flow velocity was found to be within 5% of the actual value. This prototype was then used to determine labial blood flow in 10 healthy volunteers. Simultaneous Doppler/OCT images were coupled to produce functional images of labial blood flow.

Results

Labial blood flow velocity was calculated by tracking the Doppler shifts arising from moving particles that scatter light within the tissue. Blood flow velocity ranged from 6.1 to 63.0 mm/sec in the upper lip and 8.2 to 53.2 mm/sec in the lower lip. We successfully overlaid OCT and Doppler velocity signals producing blood flow images in all of the sites examined. The imaged vessels were located in the anatomical region of the long and short capillary loops found within the labial submucosa (Figure 1).

Conclusions

OCT is a versatile diagnostic system that depicts soft and hard tissue boundaries of the periodontium with a precision of measurement that is not possible using traditional methods. We have established the feasibility of Doppler OCT to image blood flow within tissues of the oral cavity. The advantage of Doppler OCT is that the relationship of blood flow and microscopic anatomy can be precisely determined, providing a functional component for OCT imaging. In future studies we will adapt this system toward quantifying blood flow in the periodontal tissues, where we believe that OCT has the exciting potential to distinguish active from nonactive periodontitis.

This work was funded by the National Institute of Dental and Craniofacial Research: R01-DE 11154-10.

References


Figure 1: An in vivo blood flow Doppler/OCT image of the lower lip of a female volunteer. The imaged area covered 1.6 mm of the mucosal surface. A capillary long loop is detected (blue) just inferior to the epithelial surface running perpendicular to the direction of the OCT scan.
Peaks and Valleys: A Three-Year Case Study Examining the Use of Diode Laser-Assisted Periodontal Therapy

Paula Casper has been a part of dentistry for 31 years. She began her career as a Dental Assistant, graduating from Westchester School for Medical and Dental Assistants in 1973. She is a graduate of Palm Beach Community College, Dental Hygiene program. Additionally, she received her Bachelors Degree from Barry University, Miami, Florida. Since becoming a hygienist, she has worked in public health and private practice. Ms. Casper began using lasers in 1999 and attained Advanced Proficiency for the diode in 2001. She has presented during annual conferences of the Academy of Laser Dentistry and has 12 years in dental hygiene education. She is currently serving as Auxiliary Committee Chair for ALD and practicing dental hygiene in Colorado. Ms. Casper may be reached via e-mail at casperpa@aol.com.

Disclosure: Ms. Casper receives honoraria for teaching and has no financial interest in any laser company.

Pretreatment

A. Diagnostic Tests
1. Clinical Examination
A 40-year-old male presented in March 2000 complaining of severe pain in the maxillary left quadrant. A comprehensive dental examination was performed and the patient was scheduled for treatment of tooth #15.

Dental History: This patient had not sought dental care in the past five years and stated he was worried about the condition of his aging alloy restorations.

Medical History: The patient’s medical history revealed no medical abnormalities or predisposing risk factors.

Oral Examination: The patient had 28 teeth with an extensive restorative history. Rampant recurrent decay was charted. All existing restorations were in poor condition with numerous fractures and loss of marginal integrity. The restoration on tooth #15 was missing and the distal aspect of tooth structure was fractured 4 mm below the CEJ. Generalized moderate wear patterns were noted. Tissues appeared bluish-red with diffuse spontaneous bleeding upon probing. Papillae were bulbous, spongy and edematous. Generalized moderate-to-heavy plaque and calculus were noted throughout the dentition (Figure 1).

2. Radiographic Examination
Full-mouth and panoramic radiographs were taken, revealing extensive carious activity. Slight-to-moderate horizontal bone loss was evident.

3. Soft Tissue Tests
A six-point full-mouth periodontal probing was performed. The following indices were recorded: Recession of 1-2 mm was noted on teeth #6, 11, 21, and 28. Slight mobility was noted on teeth #8, 9, 24, and 25. No furcations were evident and 69% (112 of 162 sites) exhibited spontaneous bleeding when probed. Periodontal probing depths ranged from 3 to 6 mm, 53% (87 of 162 sites), with localized 7 mm depths on the lingual aspects of #14 and #15. An adequate zone of attached gingiva was present (Figures 2 and 3).

4. Hard Tissue Test and Tooth Vitality
Decay was found on 53% of the patient’s 28 teeth. All teeth were vital except #15.

5. Other Test
The occlusion was determined to be Angle’s Class I. The TMJ function was noted as normal with no pain or noises detected.

B. Diagnosis and Treatment Plan
1. Provisional Diagnosis
Moderate-to-severe periodontal disease, Type III, with moderate-to-severe diffuse gingival inflammation.

2. Treatment Plan Outline
Four quadrants of scaling with micro-ultrasonics and hand instrumentation followed by bacterial reduction and epithelialization of soft tissues with a diode laser. Comprehensive oral hygiene instruction and postoperative instruction would complete each appointment. The patient would be seen for four 1-hour sessions approximately 1-2 weeks apart. Previously treated quadrants would receive bacterial reduction with the laser during subsequent treatment sessions. One-month postoperative evaluation would be performed, utilizing the laser for bacterial reduction in all four quadrants. A three-month maintenance regime would be established.

3. Treatment Alternatives
Traditional dental hygiene modalities without the adjunctive use of the laser and/or referral for periodontal surgery.

4. Indications for Laser Treatment
The diode laser has U.S. FDA clearance for soft tissue removal in the sulcus. The diode laser wavelength is absorbed by melanin and hemoglobin, has good depth of penetration, and promotes coagulation. This treatment modality enhances the removal of diseased sulcular tissues with reduced need for local anesthesia, reduced bleeding and postoperative discomfort.

5. Contraindications for Laser Treatment
Care must be taken to avoid contact with tooth and bone structure.
6. Informed Consent
The risk and benefits of treatment were explained. Verbal consent was obtained from the patient.

Treatment
A. Treatment Objectives
To restore the oral tissues of this patient to a healthy state for the remainder of his life. To educate and motivate the patient to improve and maintain effective self-care.

B. Laser Operating Parameters
A diode laser (DioLase, American Dental Technologies, Corpus Christi, Texas) with a wavelength of 800-830 nanometers was utilized for all laser procedures. A 400-micron fiber was utilized and test-fired before use. Bacterial reduction was performed utilizing an uninitiated tip and the fiber was initiated with Acu Film II® articulating paper while performing de-epithelialization. Both continuous wave and pulsed repetition rates were used. Power settings ranged from 0.4-1.4 W and were influenced by tissue condition and operation mode. Laser exposure continued for 10 to 30 seconds per site.

C. Treatment Delivery Sequence
Initial debridement was performed for each quadrant utilizing micro-ultrasonic and hand instrumentation. Treatment proceeded from the most periodontal advanced quadrant to the least involved and was divided into four one-hour sessions. Treatment occurred at four, seven, eight, and nine weeks post initial assessment. A 4% Benzocaine topical anesthetic was applied to target tissues. Bacterial reduction was performed using a pulsed wave at 1.4 W for 10 to 30 seconds. Self-care and plaque control instructions were reviewed. Upon completion of active therapy, a one-month evaluation appointment was scheduled. The laser was utilized during periodontal maintenance for the next 21 months and indices were recorded at each appointment. The patient continued a three-month maintenance schedule for the next nine months; however, the laser was not utilized as adjunctive therapy and indices were recorded only one time. During the third year of re-care, laser-assisted therapy resumed as an adjunct modality of maintenance appointments and indices were recorded during each visit.

D. Treatment Records
A written notation of all treatment was entered into each patient’s record. Entries included the laser power setting, tip size, and duration of exposure. The entries also included the type of anesthesia used, procedures performed, clinical evaluation, and instructions administered to patient. Radiographs, periodontal charting, and images are held in digital files.

E. Postoperative Instructions
Postoperative instructions given to the patient included warm salt water rinses for 2-3 days. Ibuprofen or analgesic of choice as needed. Dietary instructions emphasized sound nutrition and avoidance of foods that could become lodged in the sulcus. Oral hygiene instructions were reviewed and consisted of twice daily plaque removal using the modified Bass technique, an interproximal brush, and flossing.

F. Management of Complications
There were no complications during or after treatment and no side effects were noted. The patient reported little to no postoperative discomfort.

G. Prognosis
Prognosis for this case is good. The patient was compliant and motivated.

Follow-Up Care
A. Assessment of Treatment Outcomes
A clinical assessment of gingival tissues occurred throughout the treatment phase. Tissues responded rapidly to the combination of improved plaque control and laser therapy. The oral tissues were noticeably improved at each visit. The patient was motivated by the reduction of bleeding and improvement in tissue color. Periodontal tissues appeared clinically healthy, firm, pink, and stippled in areas where plaque control was complete. Sites with poor plaque removal displayed a slower rate of improvement and bled when probed. Periodontal indices improved or remained stable at each re-care visit. Three month indices revealed the most significant reduction in pocket depths, from 53% to 10% and near elimination of bleeding upon probing, 69% to 4%. Patient indices at one year were stable with 15% of pocket depths greater than 3.8 mm and 6% bleeding (Figure 7).

F. Management of Complications
There were no complications during or after treatment and no side effects were noted. The patient reported little to no postoperative discomfort.

G. Prognosis
Prognosis for this case is good. The patient was compliant and motivated.

Follow-Up Care
A. Assessment of Treatment Outcomes
A clinical assessment of gingival tissues occurred throughout the treatment phase. Tissues responded rapidly to the combination of improved plaque control and laser therapy. The oral tissues were noticeably improved at each visit. The patient was motivated by the reduction of bleeding and improvement in tissue color. Periodontal tissues appeared clinically healthy, firm, pink, and stippled in areas where plaque control was complete. Sites with poor plaque removal displayed a slower rate of improvement and bled when probed. Periodontal indices improved or remained stable at each re-care visit. Three month indices revealed the most significant reduction in pocket depths, from 53% to 10% and near elimination of bleeding upon probing, 69% to 4%. Patient indices at one year were stable with 15% of pocket depths greater than 3.8 mm and 6% bleeding (Figure 7).
During the next nine months treatment was delivered by an alternate hygienist. Maintenance did not include adjunctive treatment with the laser and indices were recorded once. I resumed care of this patient in September 2003. Indices had risen to 14% pocket depth and 28% bleeding upon probing (Figures 10 and 11).

At this time the patient was re-enrolled in active therapy following the original treatment protocol. Additionally, the laser was used for bacterial reduction at each re-care visit. Rapid and significant improvement occurred in the patient's periodontal health status when the laser was reintroduced as a treatment modality. Indices as of September 2004 were 6% pocket depth and 2% bleeding upon probing.

B. Complications

The patient reported no postoperative discomfort after re-care or retreatment appointments. There were no side effects or complications experienced.

C. Long-Term Results

Excellent long-term results are expected with continued three-month re-care intervals, use of the laser for bacterial reduction and/or re-treatment when necessary, and compliant self-care. Figure 12 shows a pre-operative radiograph of the lower right molar teeth. Almost four years later, Figure 13 shows well-defined and more dense osseous crestal tissue, indicating a more healthy state.

D. Long-Term Prognosis

A long-term prognosis for health is highly probable, assuming the patient is compliant with self-care and seeks regular professional care.

Figure 14 graphically displays the various conditions of pocket depth, bleeding on probing, and amount of plaque recorded during each continuing care visit.
In his editorial, “Mitochondria, Mice, and Men” (page 7), Dr. Don Patthoff identifies the importance of investigating the effect of laser light on intracellular components. One recent study in the dental world conducted by John Wataha and colleagues explores the effect of light emitted by various curing lights (including laser) on mitochondria and cellular function. Further research will elucidate the implications and effects of intraoral use of light for diagnostic and therapeutic purposes on the cellular level.

Dr. Akira Aoki evaluates the use of an Er:YAG laser for periodontal osseous surgery (page 13). Readers of this journal and its predecessor publication Wavelengths will recall previous citations of the effects of lasers on bone tissue (Wavelengths 2002;10(1):26 and 2002;10(4):22-23). Among Dr. Aoki’s colleagues, Dr. Sasaki and others explore the ultrastructural effects of Er:YAG laser radiation on bone, in the abstract below.

Dr. Emil Litvak discusses a technology to increase the ablation efficiency of an Er:YAG laser on hard tissue (page 14). The ablation rate of dentin and enamel were last explored in this column several years ago (Wavelengths 1996;4(2):8). Another investigation of the cutting efficiency of a laser on enamel was published by Levy and colleagues in 1998, as shown below.

Dr. Linda Otis and associates report the use of optical coherence tomography on oral soft tissues (page 16). This noninvasive optical technique was last discussed in Wavelengths 1999;7(3):8, 16. As might be anticipated, this technology is also being investigated for its applicability on hard tissue. One such study involves the imaging of caries lesions and lesion progression, as described by Daniel Fried and colleagues, below.

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.

---

**Research Abstracts**

*Editor's Note: The following three abstracts are offered as topics of current interest. Readers are invited to submit to the editor inquiries concerning laser-related scientific topics for possible inclusion in future issues. We’ll scan the literature and present relevant abstracts.*

---

**Biological Effects of Blue Light from Dental Curing Units**

John C. Wataha, Petra E. Lockwood, Jill B. Lewis, Frederick A. Rueggeberg, Regina L. W. Messer

Medical College of Georgia, Augusta, GA


Objectives: This study assessed the effects of three common dental photocuring light sources (quartz-tungsten-halogen (QTH), plasma-arc (PAC), and laser) on the cellular function of fibroblasts *in vitro*. Methods: Mouse fibroblasts were exposed to light from dental photocuring units for clinically relevant durations, with total energy exposures ranging from 1.3 to 60 J/cm². The temperature rise of the cell-culture medium was measured to assess any possible effect from temperature increases, and cellular function was assessed by succinic dehydrogenase (SDH) activity of mitochondria. To directly compare the three light sources, additional experiments were done using equivalent total energy exposures from each source by adjusting the exposure durations for each unit. Results: In experiments that used clinically relevant exposure durations for each light, exposures ranging from 5 J/cm² (laser) to 15 J/cm² (PAC, QTH) irreversibly suppressed SDH activity nearly 100% when compared to no-light controls up to 72 hours post-exposure. For the PAC and QTH sources, exposures as low as 3.5 J/cm² also irreversibly suppressed SDH activity. When equivalent energies were used from each light source, exposures of 1 J/cm² did not suppress SDH activity for the QTH and laser sources, but significantly (50%) suppressed SDH for the PAC source, indicating a difference in the biological effects of the outputs of the different curing units. Equivalent energy exposure experiments also indicated a definite dependence of SDH activity on the total light energy of exposure. Temperature rises ranged from 2 to 9 degrees C, and elevated temperatures lasted for 60-300 seconds above the base temperature of 37 degrees C, but peak temperature and the duration of temperature elevation were not always related and depended on the light source used. Significance: Results from the current study indicate that these photocuring sources pose some risk of disrupting cellular function *in vivo*. Further study is necessary in other cell types and under more clinically relevant conditions to estimate the *in vivo* risk of photocuring to oral tissues.

Copyright 2004 Elsevier
Ultrastructural Analysis of Bone Tissue Irradiated by Er:YAG Laser
Katia M. Sasaki, Akira Aoki, Shizuko Ichinose, Isao Ishikawa
Tokyo Medical and Dental University, Tokyo, Japan

Background and Objectives: The use of erbium:yttrium aluminum garnet (Er:YAG) laser has been suggested for bone ablation, however, little is known about the nature of the tissue after irradiation. This study was aimed to analyze the ultrastructure of bone tissue treated with Er:YAG laser, as compared to those treated with CO₂ laser and bur drilling. Study Design/Materials and Methods: Parietal bones of Wistar rats were treated and analyzed by light microscopy, transmission electron microscopy (TEM), electron diffraction analysis and energy dispersive X-ray spectroscopy (SEM-EDX).

Results: This study demonstrated that Er:YAG laser irradiation resulted in a very thin changed layer of approximately 30 micron thickness, which consisted of two distinct sublayers: a superficial, greatly altered layer and a deep, less affected layer. Conclusions: The major changes found on bone surface after Er:YAG laser irradiation consisted of micro-cracking, disorganization, and slight recrystallization of the original apatites and reduction of surrounding organic matrix.

Copyright 2002 Wiley-Liss, Inc.

Cutting Efficiency of a Mid-Infrared Laser on Human Enamel
Guy Levy, Gilles F. Koubi, Leo J. Miserendino
University of Marseilles, France

In this study, the cutting ability of a newly developed dental laser was compared with a dental high-speed handpiece and rotary bur for removal of enamel. Measurements of the volume of tissue removed, energy emitted, and time of exposure were used to quantify the ablation rate (rate of tissue removal) for each test group and compared. Cutting efficiency (mm³/s) of the laser was calculated based on the mean volume of tissue removed per pulse (mm³/pulse) and unit energy expended (mm³/J) over the range of applied powers (2, 4, 6, and 8 W). The specimens were then examined by light microscopy and scanning electron micrographs for qualitative analysis of the amount of remaining debris and the presence of the smear layer on the prepared enamel surface. Calculations of the cutting efficiency of the laser over the range of powers tested revealed a linear relationship with the level of applied power. The maximum average rate of tissue removal by the laser was 0.256 mm³/s at 8 W, compared with 0.945 mm³/s by the dental handpiece. Light microscopy and scanning electron micrograph examinations revealed a reduction in the amount of remaining debris and smear layer in the laser-prepared enamel surfaces, compared with the conventional method. Based on the results of this study, the cutting efficiency of the high-speed handpiece and dental bur was 3.7 times greater than the laser over the range of powers tested, but the laser appeared to create a cleaner enamel surface with minimal thermal damage. Further modifications of the laser system are suggested for improvement of laser cutting efficiency.

Copyright 1998 American Association of Endodontists

Imaging Caries Lesions and Lesion Progression with Polarization Sensitive Optical Coherence Tomography
Daniel Fried, John Xie, Sahar Shafi*, John D.B. Featherstone, Thomas M. Breunig, Charles Le
University of California, San Francisco, California *California State University, Fresno, California

New diagnostic tools are needed for the characterization of dental caries in the early stages of development. If carious lesions are detected early enough, they can be arrested without the need for surgical intervention. The objective of this study was to demonstrate that polarization sensitive optical coherence tomography (PS-OCT) can be used for the imaging of early caries lesions and for the monitoring of lesion progression over time. High-resolution polarization resolved images were acquired of natural caries lesions and simulated caries lesions of varying severity created over time periods of 1 to 14 days. Linearly polarized light was incident on the tooth samples and the reflected intensity in both orthogonal polarizations was measured. PS-OCT was invaluable for removing the confounding influence of surface reflections and native birefringence necessary for the enhanced resolution of the surface structure of caries lesions. This study demonstrated that PS-OCT is well suited for the imaging of interproximal and occlusal caries, early root caries, and for imaging decay under composite fillings. Longitudinal measurements of the reflected light intensity in the orthogonal polarization state from the area of simulated caries lesions linearly correlated with the square root of time of demineralization indicating that PS-OCT is well suited for monitoring changes in enamel mineralization over time.

Copyright 2002 Society of Photo-Optical Instrumentation Engineers