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EDITOR’S VIEW
Optical Methods for the Enhancement of Dental Practice ...............116
John D.B. Featherstone, MSc, PhD

GUEST EDITORIAL
The Transformative Dental Experience ...........................................118
Alan J. Goldstein, DMD

COVER FEATURE
Use of the Dental Operating Microscope in Laser Dentistry: Seeing the Light ..............................................................122
Glenn A. van As, DMD

CLINICAL/SCIENTIFIC REVIEW
Detection of Caries by DIAGNOdent: Scientific Background and Performance ....................................................130
Raimund Hibst, PhD

Er:YAG Laser-Assisted Implant Periapical Lesion Therapy (IPL) and Guided Bone Regeneration (GBR) Technique: New Challenges and New Instrumentation ..............................................135
Avi Reyhanian, DDS; Donald J. Coluzzi, DDS

ADVANCED PROFICIENCY CASE STUDIES
Introduction ..........................................................................................................142

Nd:YAG Laser Use in Treatment of Moderate Chronic Periodontitis .................................................................144
Mary Lynn Smith, RDH

Treatment of a Subcrestal Tooth Fracture with the Er:YAG Laser ....151
Charles R. Hoopingarner, DDS

RESEARCH ABSTRACTS
Laser Bactericidal Effects on Intraoral Implants ........................................156

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Optical Methods for the Enhancement of Dental Practice

John D.B. Featherstone, MSc, PhD, San Francisco, California


SYNOPSIS

John Featherstone, editor-in-chief, describes some of the highlights of this issue of the Journal of Laser Dentistry, emphasizing the broad applications of optical technology in daily practice.

The use of light technology in the practice of everyday clinical dentistry is not restricted simply to lasers. Clinicians have examined the tissues of the mouth by eye forever. The human eye is one of the best optical tools that we have. New optical tools are now available for the practitioner and additional new ones are on the horizon. These will be highlighted in future issues. What remains is to understand what these tools have to offer and to make the best use of them for the benefit of the patient.

Microscopes have been used in laboratory settings and in clinical medicine for a long time. More recently the dental profession has started to embrace the use of microscopes on a routine basis, especially in endodontics. So why not for dentistry with lasers? In this issue the Academy of Laser Dentistry 2006 Leon Goldman awardee, Dr. Glenn van As, reviews the background and how the use of microscopes has revolutionized his daily practice.

Until recently caries detection has been largely visual, tactile, and has relied on the use of radiography where the eye could not see. New tools are coming on the market to aid the clinician in the detection of carious lesions. Laser fluorescence is the science behind one such tool. Dr. Raimund Hibst, one of the scientists involved in the research that led to the practical use of this methodology, provides a review in this issue of the science, laboratory assessment, and clinical evaluation of one of these tools.

Periodontal therapy can be enhanced by the use of lasers. As time goes on we are achieving a better understanding not only of the science behind the use of lasers for periodontal uses but also learning how better to use lasers in everyday practice. Several articles in this issue provide practical illustrations of the benefits of laser technology in this area of dentistry. The dentist and the hygienist can work closely together for the benefit of the patient.

So what does all this mean? The standard of care in dental practice is evolving. Judicious use of optical technology in clinical practice requires ongoing education, sharing of science, practice, clinical studies, case reports, and most importantly the engaging of the brain before embarking on laser-assisted procedures. The Journal of Laser Dentistry offers a mix of science and practice, including clinical and laboratory studies, reviews, and case studies. It is over to the reader to make the best use of the information for their education and most importantly the better health of the patient.

Finally, then, let us put this in perspective. In the guest editorial in this issue, Dr. Alan Goldstein addresses the philosophical issue that is generated by my statements in the preceding paragraph. He states “In my office, I take the position that our task is to make every patient experience transformative.” In order to do that we must truly understand what we are doing, what the likely outcomes are, and combine science, training, and experience together to this end. We must all be continual learners and work out how to apply our learning to whatever we do each day.

Please enjoy this issue of the Journal. Feel free to e-mail me with suggestions, criticisms, or compliments at jdbf@ucsf.edu.

AUTHOR BIOGRAPHY

Dr. John D.B. Featherstone is Professor of Preventive and Restorative Dental Sciences and Interim Dean in the School of Dentistry at the University of California, San Francisco (UCSF). He has a Ph.D. in chemistry from the University of Wellington (New Zealand). His research over the past 33 years has covered several aspects of cariology (study of tooth decay) including fluoride mechanisms of action, de- and remineralization of the teeth, apatite chemistry, salivary dysfunction, caries (tooth decay) prevention, caries risk assessment, and laser effects on dental hard tissues with emphasis on caries prevention and early caries removal. He has won numerous national and international awards including the T.H. Maiman award for research in laser dentistry from the Academy of Laser Dentistry in 2002, and the Norton Ross Award for Clinical Research from the American Dental Association in 2007. In 2005 he was honored as the first lifetime honorary member of the Academy of Laser Dentistry. Dr. Featherstone has published
more than 200 papers. He is the editor-in-chief of the Journal of Laser Dentistry.

Disclosure: Dr. Featherstone has no personal financial interest in any company relevant to the Academy of Laser Dentistry. He consults for, has consulted for, or has done research funded or supported by Arm & Hammer, Beecham, Cadbury, GSK, KaVo, NovaMin, Philips Oralcare, Procter & Gamble, OMNII Oral Pharmaceuticals, Oral-B, Wrigley, and the National Institutes of Health.

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The Journal of the Academy of Laser Dentistry ISSN# 1935-2557.

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In times of change, learners inherit the Earth, while the learned find themselves beautifully equipped to deal with a world that no longer exists.

— Eric Hoffer

The skills and knowledge that created the problem will be insufficient in the development of its solution.

— Albert Einstein

The spring 2007 issue of the Journal of the New York State Academy of General Dentistry published an article by Dr. Robert Willis that emphasized the role of emotions over logic as patients made decisions about proposed treatment plans. It is a perspective that has its roots all the way back to Dale Carnegie’s decades-long bestseller first published in 1936, How to Win Friends and Influence People. But is Dr. Willis right? Is this emotional component valid or over-hyped? What are we, as scientists, researchers, and clinicians to believe in our statistically laden and evidence-based world?

As well we might inquire whether this logic/emotion dichotomy is valid. I don’t think so. I believe it is only when we synthesize emotion and logic that we have the capacity to move people, to transform them. This is a perspective that is different from the teacher whose goal is to teach laser-tissue interaction to her students or from the practitioner whose goal is to fix teeth and eradicate periodontal disease. While these are all good things to achieve, essential things if you will, I want to achieve more.

In my office, I take the position that our task is to make every patient experience transformation. I want our patients to be changed by their interaction with us. Some might consider it preposterous and grandiose, but I would happily extend this challenge to all of us in every activity we undertake, either as a scientist or clinician. I maintain that it is the only attitude to take if leadership is embodied in our work. If we are alive and open to the ever-expanding world before us, every interaction that has its beginning in the world of test tubes, microscopes, or humans has the capacity to be transformative.

As scientists and clinicians we are both practitioners and learners. In the former sense we dispense knowledge and craft; in the latter we take in. It is very difficult, probably impossible, to make the distinction between the learner and what it is that is learned – the scientist from the science or the clinician from clinical outcomes achieved. Sure, there is a great deal to be employed, integrated, and dispensed in our scientific community — skills, content, updating, and information-gathering strategies — and we are obligated to do the best we can. But I’d like to focus on the side that I think is most important in the transformational experience: learning.

Learning has a vibrant and exploratory quality. Its root is education, a word that comes from the Latin verb educare, which means to lead. Truly learning is leading – not only leading others, but leading ourselves to new ways and seeing, knowing, and doing.

Learning means going into uncharted territory, opening and reshaping knowledge. This of course requires both a questioning mind and a courageous spirit. What does this involve for us in the world of dentistry and laser technology? How do we use our learning to open new horizons in the care we provide, to explore new clinical applications while still appreciating the science that supports them, and to bridge new practice and established theory? In short, how do we create the transformative experience?

Albert Einstein, whose life is explored in the revealing new biography by Walter Isaacson, and to whose inquisitiveness and genius we owe the foundations of laser science and laser dentistry said, “The value of a college education is not the learning of many facts but the training of the mind to think.” Thinking is far more challenging and rewarding than simply performing.

In our world of laser technology, we begin with valid scientific principles, ground them in sound clinical practice, apply our inquisitiveness to new techniques, and at the end of this process wind up with potential breakthroughs in patient care. Of course, one has to
be radical to take the risks that our conservative profession says are beyond the bounds of our do-no-harm charge. But risk-free and do-no-harm are not equivalents. No care is risk-free, and neither is life. We run risks when we invade teeth with a handpiece, we run risks when do a simple a procedure like a prophylaxis. Certainly even the most prudent in our profession would acknowledge that risks increase in direct proportion to our zeal to do good and the scope of our efforts. And yes, we can mitigate these risks with education, training, and experience. But risk cannot be eliminated, ever. Do nothing and the risk of malpractice looms large.

There is irony here. Many colleagues, often those least familiar with the principles of laser technology, see our unique armamentarium through their own conservative, do-no-harm prism. A drill that creates micro (and not-so-micro) fractures is seen as proper; while laser energy that creates small, easily restorable, virtually sterile cavities without fractures is seen as radical. It is language that has turned dentistry on its head. This inversion of science extends to the discussion of laser technology for soft-tissue care. Excisional treatment is deemed conservative and appropriate, while care offered at the multiple-cell layer level — which has the added benefit of being bactericidal — is deemed radical and without value. Am I missing something?

My point is that I sometimes see our profession as learned, in the sense described by Eric Hoffer above — and yet it often refuses to acknowledge that learning is the activity most urgently required. Confucius identified the first and essential virtue as courage. I have a feeling I know where he would come down on this question of whether every interaction is potentially, and optimally, transformative — and what it takes to achieve it.

AUTHOR BIOGRAPHY
Born and raised in the Bronx, Dr. Alan Goldstein graduated from the City College of New York before receiving his dental degree from the University of Pennsylvania School of Dental Medicine in 1968. He is a frequent contributor to the dental literature as well as a lecturer in a variety of venues. He was certified as a Professional Coach in 2001 and often addresses audiences on topics of personal effectiveness, fulfillment, and leadership as well as dental practice management and use of lasers. He is a past president of the Academy of Laser Dentistry and a former editor of Wavelengths. He serves on the Dental Advisory Board of Dentistry Today and the Journal of Laser Dentistry. Dr. Goldstein may be contacted by e-mail at: llaama1@mindspring.com.

Disclosure: Dr. Goldstein has provided educational services for a number of laser manufacturers and received honoraria for these services. Presently he has no commercial financial relationships.

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<table>
<thead>
<tr>
<th>Illustration Type</th>
<th>Definition and Examples</th>
<th>Preferred Format</th>
<th>Required Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line Art and Vector Graphics</td>
<td>Black and white graphic with no shading (e.g., graphs, charts, maps)</td>
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<td>1200 DPI</td>
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<tr>
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<td>TIFF or JPG</td>
<td>300 DPI (black &amp; white) 600 DPI (color)</td>
</tr>
<tr>
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<td>Combination of halftone and line art (e.g., halftones containing line drawing, extensive lettering, color diagrams)</td>
<td>EPS or JPG</td>
<td>1200 DPI</td>
</tr>
</tbody>
</table>
Use of the Dental Operating Microscope in Laser Dentistry: Seeing the Light

Glenn A. van As, DMD, North Vancouver, British Columbia, Canada


SYNOPSIS
Dr Van As was the recipient of the Leon Goldman Award for clinical excellence in laser dentistry in 2006. This article reviews his pioneering work using microscopy-assisted laser dentistry.

INTRODUCTION
The virtue of high levels of magnification in the medical field had been understood for many decades. In 1981, Apotheker introduced an operating microscope into dentistry, although it offered only a single level of magnification and could be used only in a standing position.

In the late 1980s and early 1990s, endodontists began to promote the dental operating microscope (D.O.M.) for its value in standard endodontic therapy and for the improvements in outcome of both nonsurgical retreatments and for surgical cases.

At the same time, periodontists utilized the D.O.M. along with their microsurgical armamentarium, realizing reductions in postoperative pain and quicker healing.

The use of lower-power telescopic loupes became more of the norm for all of dentistry during the mid-to-late 1990s. With better understanding of the role and value of magnification, many practitioners purchased a higher-power set of loupes along with an illuminating headlight. As the present decade has progressed, the greatest increase in new users of the D.O.M. has been from those clinicians who routinely used loupes. In fact, in 2001, the author coined the term “magnification continuum” to describe the ever-increasing powers of magnification being used in dentistry.

The use of the operating microscope for both diagnosis (new patient examinations, earlier visualization of decay and cracks) and treatment (including laser dentistry) has become more accepted.

This article examines the ability of the microscope to provide improvement in visual acuity and the effect that high levels of enhanced magnification and illumination can have on improving the quality of laser dentistry that is provided.

Figure 1: View of a microscope-centered dental operatory
Figure 2: Neutral and balanced ergonomics of the author at the microscope
Figure 3: Digital documentation

ABSTRACT
This article discusses the history and role of the dental operating microscope in dentistry. The microscope has become a standard part of the endodontic armamentarium since the 1980s as practitioners recognized the value of improved visual acuity through enhanced magnification and illumination. Benefits of the dental operating microscope including improvements in treatment outcomes, ergonomics, documentation, and communication are described. The importance of high levels of magnification for hard tissue laser dentistry are emphasized and detailed as this discipline, like endodontics, is also largely reliant on nontactile information for clinical success.

BENEFITS OF MICROSCOPE-CENTERED PRACTICES
When used routinely for all aspects of dentistry, the microscope has four basic advantages:
1. Improved precision of treatment
2. Enhanced ergonomics (Figure 2)
3. Ability to capture digital documentation (Figure 3)
4. Enhanced communication through integrated video.
1. Improved Precision of Treatment

The visual information provided by the operating microscope is in fact not indicative of the magnification that is being employed. The actual amount of visual information is the area of view through the scope and is therefore the product of the horizontal times the vertical number of pixels. Therefore, the clinician using the 2X magnification power of entry-level loupes sees approximately 4 times the visual information of a dentist not using any magnification (unaided eye). Likewise, 3X loupes provide 9 times the visual information of the unmagnified view and more than double the view of the 2X set. Table 1 summarizes the relative advantages of a variety of magnifications.

The author uses his microscope typically at 10X magnification which provides 100X the amount of visual information compared to the unaided eye view. This is 25 times the information from 2X loupes and more than 10 times as that seen with 3X.

Carr\textsuperscript{22} reported that the unaided human eye has the inherent ability to resolve or distinguish two separate lines or entities that are at least 200 µm or 0.2 mm apart. If the lines are closer together, then even 20/20 unmagnified vision will not allow the clinician to resolve them as two separate entities and the objects will appear as one. Thus with magnification the resolution of the human eye improves dramatically (Table 2).

Baldissara et al.\textsuperscript{53} showed that the experienced clinician, when using a sharp, new explorer, can feel marginal gaps of around 36 µm. Thus, when

---

**Table 1: Comparison of Unaided Eye, 2X Loupes, and Other Levels of Magnification**

<table>
<thead>
<tr>
<th>Magnification</th>
<th>Visual Information (VI)</th>
<th>VI Compared to 2X Loupes</th>
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<tbody>
<tr>
<td>Unaided eye</td>
<td>1X</td>
<td>1/4</td>
</tr>
<tr>
<td>2X loupes</td>
<td>4X</td>
<td>Even = 1</td>
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<td>3X loupes</td>
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<td>4X loupes</td>
<td>16X</td>
<td>4</td>
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<td>6X microscope</td>
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<td>9</td>
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**Table 2: Resolution vs. Assessment Method**

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Figure 3: Illustration of the convenient arrangement of video camera on the left and a digital, single lens reflex camera (Nikon D70) on the right of the scope

Figure 4: Views of the same tooth area showing the effect of the magnification range of a typical microscope
magnification is beyond 6X power, the effectiveness of tactile means of inspection with an explorer significantly decreases. Many clinicians using a microscope now rely on visual rather than tactile means of discovery as their motor skills improve during the learning curve.

The increased amount of information provided by the microscope offers some challenges. As the magnification increases, the depth and diameter of the field of view in the operating field decreases. At higher magnification, there is an increased demand for improved control of the micromotor muscles and joints (fingers and wrists) that can require stabilization of the gross motor joints (elbow and shoulder) with micro-surgeon chairs. Tibbets and Shanelec reported the medical literature showed that the clinician not using magnification made movements that were 1-2 mm at a time. At microscope levels of 20X magnification, the refinement in movements can be as little as 10-20 µm (10-20/1000ths of a millimeter) at a time. It is useful therefore to note that the limitation to precision of treatment is not in the hands but in the eyes.

Impact of Improved Visual Acuity in Laser Dentistry
The ability to carefully evaluate laser-tissue interaction at high magnification is important in many areas of laser dentistry. The microscope offers improved visual acuity through its enhancements in magnification (Figure 4) and coaxial, shadow-free illumination, and these properties can be of tremendous benefit during both soft tissue and hard tissue ablation procedures.

Soft Tissue Laser Procedures and the Dental Operating Microscope
The microscope can be especially effective for clinicians using laser wavelengths with small-diameter flexible optic fibers for soft tissue procedures, such as with potassium titanyl phosphate (KTP), diode, and Nd:YAG lasers. For example, using a laser to trough around subgingival crown preparations can be frustrating because dragging the glass tip through inflamed tissue creates more bleeding. A 300-micron fiber, which is close to the resolution of the human eye, must be accurately placed 1 mm or so into the sulcus to distend it, not to deepen it or to remove the papilla. The ability to closely watch the laser-tissue interaction is important to prevent excessive heat, while accurately aiming the end-cutting fiber at the target tissue. The magnified view should prevent tissue charring, and thus decrease any postoperative discomfort for the patient (Figures 5a-5f).

Excisional or incisional surgical procedures using small optic contact fibers can be performed with added precision when viewed through the D.O.M. The clinician can easily visualize exactly when all tissue fibers have been ablated, reducing the need for retreatment due to relapse.

In microscope-assisted noncon-
tact soft tissue ablation, the clinician can keep the laser power settings lower and avoid iatrogenic damage to nontarget adjacent tissues. Magnification provides another advantage when the practitioner, using either erbium or carbon dioxide laser energy, is trying to avoid accidental interaction with tooth structure or bone.

Other noncontact procedures, such as aphthous ulcer desensitization, hemostasis of extraction sites, and treatment of hemangiomas, can benefit from the visual acuity offered by magnification. Examples are shown in Figures 6a-6f.

The erbium laser wavelengths (Er:YAG, Er,Cr:YSGG) may be used in contact or noncontact mode for soft tissue procedures. Using the noncontact mode can help to limit the inherent weakness of the erbium energy to adequately coagulate. The noncontact “plasty” or shaving down of tissue that is possible with the chisel or large footprint Er:YAG tips, when used in conjunction with the microscope

Figure 6: Examples of procedures that benefit from observation by magnification

Figure 6a: Preoperative view of lower second molar

Figure 6b: Sinus tract on buccal aspect

Figure 6c: Extraction complete

Figure 6d: Hemostasis by diode laser treatment

Figure 6e: Hemostatic laser-induced clot viewed at low magnification

Figure 6f: Clot induced by diode laser viewed at high magnification

Figure 7: Examples of Er:YAG or Er, Cr:YSGG laser procedures that can be better carried out under magnification

Figure 7a: Noncontact Er:YAG frenectomy. Note early charring before adjusting power settings

Figure 7b: High-magnification view of frenectomy. Note lack of hemorrhage in noncontact mode

Figure 7c: Noncontact “plasty” of epulis on maxillary lip. Note “flash” at ablation site

Figure 7d: High-magnification view of frenectomy after periosteum is “scored” with an Er:YAG laser
Hard Tissue Laser Ablation and the Operating Microscope

Leknius and Geissberger as well as Zaugg et al. demonstrated that, when magnification was incorporated, procedural errors in restorative treatment decreased significantly. In the latter study, the use of a microscope resulted in fewer errors than loupes. Utilizing conventional instruments, the clinician can rely upon tactile means from burs or hand instruments to determine when the carious lesion is fully excavated or when old restorations have been completely removed. These same tactile methods become more unreliable in hard tissue laser dentistry where so much of the evaluation of the laser-tissue interface is based on visual cues. Caries detection dyes are not easy to use and can produce false readings with hard tissue laser preparations (Figures 8a-8f). Moreover, erbium lasers can use both contact tips (where the actual distance for effective ablation is 0.5 - 1.5 mm from the surface) and noncontact delivery systems, and it is difficult to “feel” the ablation process. Therefore the use of high magnification is essential to determine when the preparation is complete.

There are several more reasons to employ magnification for restorative procedures. A large amount of water is needed for effective and safe hard tissue ablation, but that amount of water can obscure good visualization. Where rigid contact tips are used to deliver laser energy, their clear color makes them difficult to see. They must have a nonchipped surface, and be held at the proper working distance from the target tissue, without tactile feedback. This optimum distance can vary with different instruments, but ablation efficiency will significantly decrease as the delivery system is placed farther from the tooth. If the laser tip is brought into direct contact with the surface the cutting efficiency decreases, and the water flow is not able to wash away ablation byproducts and cool the tissue. Charring and patient sensitivity can occur. Enamel bevels for Class III, IV, and V restorations require the clinician to “scrape” or alter the ablated enamel prior to acid etching. High magnification with the operating microscope shows that enamel bevels have many loose rods which, if not altered with an instrument (hatchet or spoon, air abrasion or diamond bur), will yield significantly lower bond strength compared to bur-cut enamel. The fragments of enamel that are scraped off are easily visible under high magnification. The operating microscope is also an instrumental piece of the armamentarium for the ablation of bone. To prevent plucking or iatrogenic notching, it is best to use lower settings (1.5 - 3 Watts, for

Figure 8: Views relating to cavity preparation and restorations illustrating the benefits of using magnification

Figure 8a: Preoperative interproximal decay

Figure 8b: Decay visible on distal aspect of first primary molar

Figure 8c: High magnification shows decay still visible on facial wall of box

Figure 8d: Preparations completed

Figure 8e: Restorations finished

Figure 9: Laser beginning closed flap osseous contouring
example), a noncontact mode, and a high water flow to prevent charring and necrosis. The amount of water and slight bleeding can obscure visibility, so the ability to increase the magnification during the procedure is imperative to success.

Osseous crown lengthening to gain or re-establish biologic width can be performed with erbium lasers. The microscope is especially useful for closed-flap procedures so the clinician can more accurately direct the laser energy and avoid iatrogenic troughing of the bone. Figure 9 shows the laser beginning closed-flap osseous contouring.

It is therefore very beneficial for magnification to be used for many aspects of hard tissue laser dentistry. The higher the level of magnification used, the greater the ability of the dentist to directly view the laser-tissue interaction and to use the lowest possible energy and power to complete the procedure. This ultimately produces less patient sensitivity and better tissue health.

**Laser Safety**
Safety is of paramount importance to laser practitioners whether they are using no magnification, telescopic loupes, or higher levels of magnification. All dental operating microscopes have holders that accept wavelength filters for eye protection. As usual, the laser safety officer must ensure that the appropriate filter is in place, and the user must be sure to make close eye contact with the oculars to avoid the possibility of irradiation by accidental stray light. Assistants and patients must wear appropriate eye protection. Figure 10a shows an erbium laser filter and Figure 10b shows a filter being placed into the microscope.

2. **Improved Ergonomics**
The operating microscope allows for the dentist to sit with an upright, neutral, and balanced posture (Figure 2). This neutral and balanced posture obtainable with the D.O.M. has been discussed as being helpful in preventing ergonomic issues that plague so many dentists and seem to be an occupational hazard.

3. **Ability to Capture Digital Documentation**
The D.O.M. can be a beneficial addition in documenting a clinical case, especially because of the detailed image (Figure 3), whether still or video. Carr, Behle, and van As have written articles discussing the merits of digital documentation with the D.O.M. and the advantages of doing so.

4. **Enhanced Communication through Integrated Video**
Dentists who have added video capability to the microscope have found it useful in providing information to both patients and to auxiliaries since they can observe treatment in real time. Clinicians have found that the images from the operating scopes are a benefit to educating their patients about treatment needs and help in persuading patients to accept treatment plans.

The use of video transmitted to different monitors in the operatory has initiated the possibility of working solely from a monitor, a method some surgeons now employ. The next improvement will be the development of three-dimensional displays.

**CONCLUSION**
The operating microscope used for laser dentistry provides benefits for any clinician. The advantages are improved precision, improved ergonomics, ease of documentation, and the ability to more fully communicate with patients, staff, and colleagues. Practitioners using the combination of the dental operating microscope and lasers have found that the two technologies work well in tandem and improve not only the treatment outcome but the enjoyment of providing it.

**AUTHOR BIOGRAPHY**
Dr. Glenn A. van As is a 1987 graduate of the University of British Columbia Faculty of Dentistry who maintains a full-time private dental practice in North Vancouver, British Columbia, Canada. His areas of interest and expertise involve the utilization of the dental operating microscope for all of his clinical dentistry and in the use of multiple wavelengths of hard and soft tissue lasers for many procedures. Since 1999, he has lectured more than 200 times internationally, provided hands-on workshops, and published internationally on the value of
multiple wavelengths of lasers and practicing with the high magnifications obtainable with the dental operating microscope. Dr. van As is a member of the British Columbia Dental Association, the Canadian Dental Association, the Academy of Microscope Enhanced Dentistry (AMED), and the Academy of Laser Dentistry (ALD). He has obtained both Standard and Advanced Proficiency in laser usage from the Academy of Laser Dentistry, and was distinguished with the Leon Goldman award for clinical excellence in the field of laser dentistry in 2006. In addition, Glenn is a founding member of the Academy of Microscope Enhanced Dentistry, and in 2004-2005 served as the second president of the group (www.microscopedentistry.com). Dr. van As may be contacted by e-mail at glennvanas@shaw.ca.

Disclosure: Dr. van As receives honoraria for lectures from the Global Surgical Corporation on microscopes, from HOYA ConBio on lasers, and from Ivoclar on lasers.

REFERENCES


Detection of Caries by DIAGNOdent: Scientific Background and Performance

Raimund Hibst, PhD, Institut für Lasertechnologien in der Medizin und Meßtechnik (ILM), Ulm, Germany


INTRODUCTION

The process of dental caries is accompanied by changes in the optical properties of the affected enamel or dentin. These changes in scattering, absorption, or fluorescence are the basis of visual/optical detection of carious lesions. First, demineralization of enamel results in an enlargement of intercrystalline spaces, which makes the tissue less homogeneous and results in an increase in light scattering (especially when the tooth is dried). As a result, decalcified enamel becomes visible as a highly scattering “white spot.” Later, the presence of chromophores in the lesion enhances light absorption so that the carious lesion appears brownish.

A further tissue property which is affected by caries is fluorescence. Fluorescence is the re-emission of light by molecules after absorption. The fluorescence light always has a longer wavelength than the excitation light used for illumination. Its specific spectrum depends on the excitation wavelength and the molecular species. A variety of biological molecules shows fluorescence, especially proteins. Fluorescence of teeth on ultraviolet (UV) excitation was first described nearly one century ago:1 When teeth were illuminated with invisible UV light from a Wood’s lamp, a bright fluorescence was observed by the naked eye. As early as 1927 it was noted that plaque shows different fluorescence properties when compared to sound tooth necks.2 While all the early studies were performed with UV-excitation, the first experiments with visible light were reported beginning in 1981.3 In general, the investigations with UV, blue or green excitation light revealed a strong fluorescence of enamel, which is slightly altered when the tissue becomes carious. This phenomenon allows detection of demineralization in the outer surface regions (sometimes referred to as quantitative laser / light fluorescence, or QLF). However, strongly fluorescing healthy enamel optically masks changes in deeper layers, as scattering does, so that deeper lesions covered by intact tissue are difficult to detect by direct fluorescence changes.

RED EXCITED FLUORESCENCE

The detection of hidden (occlusal) caries requires a low fluorescence from the overlying sound enamel, and a stronger emission from the lesion. Such a situation was found when excitation by red light was investigated.4–6 Experiments showed that fluorescence yield decreased for longer excitation wavelengths, as expected, but this decrease was much more pronounced for sound surfaces than for carious lesions. With red light excitation (e.g., 655 nm) carious lesions fluoresce much more strongly. This is true across the entire emission wavelength range. Thus all fluorescence can be used for differentiation of healthy and diseased tissue. The possibility to utilize the total fluorescence light is an advantage of red excitation, which compensates in part for the lower intensities compared to excitation with shorter wavelengths. The considerable contrast between carious and sound enamel, or dentin, respectively, obtained for red excitation is demonstrated in Figure 1, which shows a hemisectioned tooth and the corresponding fluorescence image. Both carious sites are clearly marked on the very low background fluorescence level. This offers a very elegant way to detect caries, because only the bright fluorescence spots in an otherwise dark environment are readily observed. This does not require 2-dimensional images and analysis. Additionally,
the detection of hidden caries is possible, since the weaker sound enamel fluorescence does not completely mask the signal from a deeper lesion. Red light, and also infrared fluorescence radiation, is less absorbed and scattered by enamel than light of shorter wavelengths, so that in general red and infrared light penetrates deeper into the tooth. This also helps to increase the depth that can be examined.

**Fluorophore Identification**

In order to find the origin of fluorescence, one has to consider both the baseline fluorescence of sound dental tissue and its increase during the carious process.

*Sound enamel and dentin* exhibit a low, but observable, fluorescence. The dominant component of enamel and dentin is the substituted hydroxyapatite (HA) calcium phosphate mineral. Experiments with pellets pressed out of powdered HA and various other calcium phosphates revealed very low signals. So it seems unlikely that calcium phosphates are responsible for the baseline fluorescence of sound teeth. By comparing teeth with different color one can observe that whiter teeth exhibit less fluorescence compared to darker ones. Presumably the same stains cause color and fluorescence.

*Demineralized enamel* that was produced by chemical decalcification did not significantly enhance fluorescence. This corresponds to the finding of low calcium phosphate fluorescence described above. That is, simply removing mineral from these hard tissues does not significantly alter the fluorescence.

*Caries lesions* show microscopically a strong correlation between brownish discoloration and fluorescence, so that brown chromophores might also act as fluorophores (substances that fluoresce). Besides natural carious lesions, calculus of various types also fluoresce under red light, including white calculus. So besides the brown pigments other fluorophores can be present. Likely candidates are bacteria or bacterial metabolites. To test this hypothesis, bacteria from carious lesions were incubated on blood agar and analyzed by fluorescence microscopy. Both the bacterial colonies and the surrounding agar showed fluorescence. Agar fluorescence decreased with increasing distance from the colonies, indicating that there are diffusible bacterial metabolites fluorescing under red light excitation (Figure 2). Candidates for bacterial metabolites that fluoresce could be the so-called porphyrins. Porphyrins occur as intermediate steps in the synthesis of heme, and are also produced by several types of oral bacteria, such as *Prevotella intermedia* or *Porphyromonas gingivalis*. In earlier work, porphyrins, especially Protoporphyrine IX (PPIX), indeed could be extracted from carious lesions and were demonstrated to be useful in differentiating caries from sound tooth structure by violet (406 nm) excited fluorescence. Although fluorescence yield is maximal for this short wavelength excitation, porphyrins were known to also show some fluorescence when excited by red light. Solutions of these molecules also fluoresce with 655-nm excitation, and their emission spectra are very similar to those found for caries.

*Other substances* occurring naturally in the mouth, like water, saliva, blood, or soft tissue do not exhibit fluorescence with red light excitation and thus do not interfere with caries detection. In contrast, chlorophyll does fluoresce, so that stains originating from food (leaves, wine, etc.) must also be considered as an origin of fluorescence (see below).

**Detector System and Application**

On the basis of the investigations described above the optical caries detector DIAGNOdent® (DD) was developed as a joint project between the Institut für Lasertechnologien in der Medizin und Meßtechnik (ILM, Ulm, Germany) and Kaltenbach and Voigt (KaVo, Biberach, Germany).

The set-up and function are as follows. Light from a laser diode (655 nm) is coupled into an optical fiber and transmitted to the tooth. The excitation fiber is surrounded by a bundle of fibers which gather fluorescence as well as backscattered light and guide it to the

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*Figure 1: Hemisectioned tooth with approximal and occlusal caries*
detection unit (Figure 3). By the use of a band pass filter in front of the photo diode detector, the backscattered excitation and short wavelength ambient light is absorbed. To discriminate the fluorescence from the ambient light in the same spectral region, the laser diode is modulated (i.e., the laser diode intensity is varied with a certain frequency). Due to its relatively short lifetime, fluorescence follows this modulation. By amplifying only the modulated portion of the signal, the ambient light is suppressed. The remaining signal is proportional to the detected fluorescence intensity and displayed as a number (0 to 99, in arbitrary units). In order to compensate for potential variations of the system (e.g., laser diode output power), the device can be calibrated by a ceramic standard of known and stable fluorescence yield. This makes the measurement absolute (although in arbitrary units) and allows comparisons of fluorescing tooth spots over time.

Tests on solutions of varying PPIX concentrations demonstrated a linear response of the system (when the fluorophore concentration is increased by a factor of x, the signal increases by the same factor). Sensitivity was tested by applying small droplets of PPIX solution onto the enamel or dentin area of a hemisectioned tooth. On average 1 picomole of PPIX results in a signal increase of 4 DD units. This compares to the baseline levels of sound teeth, and would be the detectable amount of porphyrins in superficial carious lesions.

In practical use the DD should be calibrated regularly (maybe daily) to assure comparable readings over time. After the tooth is cleaned, a sound spot on the smooth surface is measured in order to provide a baseline value. This value is then subtracted electronically from the fluorescence of the site to be measured. In order to measure and capture the signal from the entire carious lesion, the instrument has to be tilted around the measuring site. This ensures that the tip picks up fluorescence from the slopes of the fissure walls where the caries process often begins. A rising audible tone helps the examiner to find the maximum fluorescence value of the site under study.

**PERFORMANCE**

A literature search (with Scopus; “DIAGNOdent” in title, keywords, or abstract) yields about 110 published articles on the DD. A
large portion of these address questions concerning its:
• reproducibility, reliability (probability that two measurements by the same (intraexaminer) or different (interexaminer) observers lead to the same result
• sensitivity (ratio: true positive / (true positive + false negative), i.e., probability to correctly identify carious lesions)
• specificity (ratio: true negative / (true negative + false positive), i.e., probability to correctly identify sound teeth).

A systematic review on the DD performance reveals persistent high intraexaminer and slightly lower but still good interexaminer reliability. The results on sensitivity and specificity are variable among the studies; the data range for the majority is given in Table 1.

Sensitivity and specificity depend on the cut-off values used as the threshold to discriminate carious from sound tissue. As the threshold is lowered, more lesions are detected at the price of an increasing number of false positives. The few reported in vivo studies yielded a better performance than the majority of in vitro investigations. This might be due to changes in optical properties after extraction of the teeth (increase of scattering, loss of fluorescence). In the in vivo studies, a threshold of 20 DD units was chosen (in one study, 30). This can serve as guidance for the user’s (individually variable) threshold value.

CONCLUSION
In conclusion, “the DD is clearly more sensitive than traditional diagnostic methods.” However, the increased likelihood of false positive readings compared with that of visual methods gives rise to some concern. The specificity found in the studies would mathematically predict numerous unnecessary treatments for a collective of patients with low caries prevalence. However:
• First, the studies were performed on samples with very high caries prevalence (typically 20 to 50%) with numerous suspicious areas. Specificity with respect to these samples cannot be extrapolated to the general situation, since the DD will never show an increased signal for completely intact white teeth. The reason for false positive readings is always fluorescence, originating from stains (see above), calculus, or filing material.
• Secondly, the DD is a detector and not a “diagnostic robot.” Its readings should be interpreted in the context of the situation. For example, if fissures of a tooth exhibit increased fluorescence but the surrounding area does not, it is more likely that it originates from superficial stain than from deeper caries. Even in the presence of fluorescing composites, information can be gained: An increase of fluorescence from the center to the periphery would indicate additional fluorophores (= caries) at the margin.

In contrast to visual inspection (and also radiography), the DD provides quantitative data. These are not directly reflecting to “classical” lesion parameters like mineral loss or depth expansion, but are related to the amount of fluorescing porphyrins. Since bacterial porphyrins accumulate in demineralized areas of increased depth and porosity, more severe lesions typically have higher concentrations of porphyrins. Therefore DD readings may provide quantitative data that can be related to the severity of tooth decay. DD readings are highly reproducible and this allows longitudinal monitoring of lesions. In all questionable situations with moderate fluorescence signals, it is reasonable to follow up the suspicious site at periodic examinations. Increasing fluorescence signals would indicate a progression of the lesion and thus indicate enhanced preventive or operative treatment. However, it is important to remember that the increase in fluorescence is a result of more absorption of external fluorophores into the more porous tooth structure, rather than directly detecting lesion size or extent.

Recently, a miniaturized version of the DD was released (DIAGNOdent® pen). First comparisons show that the new device performs on occlusal surfaces as well as the “classic” DIAGNOdent.32

AUTHOR BIOGRAPHY
Raimund Hibst has been educated in physics and biology. He received a PhD degree in physics from the University of Bochum, the venia legendi in biomedical engineering from the University of Ulm in 1995 (medical faculty), and in 2000 he became professor for laser and dental technologies (Faculty of Engineering, University of Ulm). Since 1986 he has been with the Institut für Lasertechnologien in der Medizin und Meßtechnik, Ulm, Germany, where he is actually associate director and the head of the Dental Technology Center. His special interest is in optical methods in dentistry. Among his projects has been the development of an Er:YAG laser system for dental and oral therapeutic applications (KEY Laser®)

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and caries detection by fluorescence, which is also now used in clinical practice (DIAGNOdent®). The Er:YAG laser research was awarded by the University of Ulm in 1990. In 1998 he received the award for best cooperation with industry. Raimund Hibst is an editor of the journal Medical Laser Application and a board member of several journals. Dr. Hibst may be contacted by e-mail at raimund.hibst@ilm.uni-ulm.de.

Disclosure: The caries detector DIAGNOdent has been developed in cooperation between ILM and KaVo. It is based on an invention made by the author and coworkers. For this, ILM receives royalties from KaVo which in part are passed down to the inventors.

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For additional references, see the works cited within references 6, 8, and 9, above.
Er:YAG Laser-Assisted Implant Periapical Lesion Therapy (IPL) and Guided Bone Regeneration (GBR) Technique: New Challenges and New Instrumentation

Avi Reyhanian, DDS, Netanya, Israel; Donald J. Coluzzi, DDS, Redwood City, California


SYNOPSIS
The etiology and predisposing factors of implant periapical lesions are described and a case report of treatment using an Er:YAG laser is presented.

INTRODUCTION
Osseointegrated implants have been utilized as a successful treatment modality over three decades, with a high reported success rate, greater than 90 percent. The predictability and high rate of success of dental implants makes them a standard treatment modality. Oftentimes in spite of exacting planning and precise placement accompanying the procedure, implant failure can and does still occur. A small number of implants fail because of operator inexperience or clinically recognizable cause. Their widespread use in recent years has produced different types of complications which can be divided into two categories:

1. Intraoperative Complications
   - Bleeding
   - Nerve injury
   - Mandibular fractures
   - Implant displacements
   - Accidental bone perforations
   - Incomplete flap closure

2. Postoperative Complications
   - Mucositis and peri-implantitis
   - Implant periapical lesion (IPL)
   - Surgical wound dehiscence
   - Lesions on adjacent teeth
   - Incomplete osseointegration.
   - Recent case reports introduced the term retrograde peri-implantitis as a lesion (radiolucency) around the most apical part of an osseointegrated implant. It develops within the first month after insertion of the implant.

The Etiology of Implant Periapical Lesion
1. Contamination of the implant surface
2. Overheating of bone
3. Overloading of the implant
4. Presence of preexisting bone and microbial pathology
5. Presence of residual root fragments and foreign bodies in bone
6. Implant placement in an infected maxillary sinus
7. Implant placement in a poor bone quality site
8. Lack of biocompatibility
9. Excessive tightening of the implant and compression of the bone chips inside the apical hole, producing subsequent necrosis
10. Contaminated implants

Predisposing Factors
1. Patient characteristics: age, medical history
2. Recipient site: local bone quality and quantity, cause of tooth loss
3. Periodontal and endodontic conditions of neighboring teeth
4. Implant characteristics: length, surface characteristics
5. Surgical aspect: guided bone regeneration, osseous fenestration, or dehiscence

ABSTRACT
Osseointegrated implants have enjoyed a success rate of more than 90 percent. There are several reasons for failure including challenges during placement and postoperative complications.

This article will discuss one of those failures, the implant periapical lesion (IPL) which is an accumulation of granulation tissue around the apical area of an implant. It is manifested as a radiographic radiolucency, and results in compromised osseous health and often requires the removal of the implant fixture.

The etiology and predisposing factors of IPL will be enumerated, and descriptions of the classification, prevention, and treatment of IPL will be elaborated.

A clinical case of IPL, treated with an erbium:YAG laser, will be presented. The detailed clinical protocol will be described. The seven-month postoperative clinical and radiographic findings show complete reversal of the lesion and change the prognosis from hopeless to good for the implant.

SYNOPSIS
The etiology and predisposing factors of implant periapical lesions are described and a case report of treatment using an Er:YAG laser is presented.

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Classification
A classification of implant periapical lesions has been suggested that separate them into two categories: inactive and infected. The inactive form is likely to appear as an apical scar, resulting from a residual bone cavity created by placing an implant that was shorter than the prepared drill site. An example is shown in Figure 1. The infected form occurs when an implant apex is placed in proximity to an existing infection or when a contaminated implant is placed (Figure 2).

Prevention and Treatment
Suggested preventions of implant periapical lesion include careful management of contaminants and heat generation during implant surgery.

Treatment would vary according to the type of lesion. The inactive type is observed and monitored. The infected type requires surgical intervention, debridement of the infected lesion, systemic antibiotic, and/or guided bone regeneration. An implant apical resection or implant removal could be performed depending on the extent of the infection and the stability of the implant.

The Use of Er:YAG Laser in IPL Treatment
- The erbium laser can make the initial flap incision, such as a crestal incision, or an intrasulcular or vertical releasing incision. The laser produces a wet incision (some bleeding) vs. a dry incision (no bleeding) such as that produced by the CO₂ laser.
- After the flap is raised, the erbium laser is also very efficient at vaporization of any granulation tissue, with a lower risk of thermal damage to the bone than current diode or CO₂ lasers.
- The erbium laser provides detoxification of implant surfaces. Studies have demonstrated this laser’s bactericidal potential.
- Furthermore, implant surface threads can be disinfected without damage by lasing directly on their surfaces with a low energy.
- The erbium laser is also efficient at remodeling, shaping, and ablating necrotic bone.

CASE OVERVIEW
This case describes the use of an Er:YAG laser in treatment of peri-implantitis of an implant periapical lesion and the advantages of this laser wavelength in performing a guided bone regeneration (GBR) technique versus conventional methods.

Examination
A 56-year-old female presented with a noncontributory medical history. She was not taking any medications. She presented two months after she had 4 implants placed in the maxillary anterior area for teeth #7, 8, 9, and 10. The fixtures of #8 and 9 had failed the previous month and were removed; the implant for #10 was integrating normally, but #7 was compromised.
The patient had fair oral hygiene and brushed and flossed daily. Periodontal probing showed 3-mm pockets with no bleeding. The implant for tooth #7 was nonsubmerged and a labial fistula was present; furthermore, insertion of a probe into the fistula led to the end of the implant, and revealed loss of facial bone on the buccal side of the implant (Figure 3). The soft tissue around the failed implants in the area of #8 and 9 had healed well, the implant at the location of #10 was submerged without soft tissue complications, and all other oral soft tissue appeared normal.

Panoramic and periapical films showed a radiolucent area around the apical portion of the implant (Figure 4). The extent of buccal bone resorption could not be determined from the radiograph.

The implant was stable with no mobility.

Diagnosis
The provisional and final diagnosis was peri-implantitis of the implant fixture for tooth #7 with an infected implant periapical lesion exhibiting severe bone loss on the buccal side of the implant.

Treatment Plan
Treatment would involve the use of an Er:YAG laser to perform:
• the incision for a flap
• ablation of granulation tissue around the implant
• remodeling, shaping, and decortication of the bone
• decontamination of exposed screw threads of the implant, and
• a GBR procedure.

Since the implant was not mobile, this technique has a good prognosis.

Treatment alternatives could consist of traditional scalpel, curettes, citric acid, air flow, air abrasion™ and rotary bone burs.

Treatment
An Er:YAG laser (OpusDuo™ AquaLite E™, Lumenis Ltd., Yokneam, Israel) with a wavelength of 2940 nm was used.

An intrasulcular incision was made using a 200-micron sapphire tip in contact mode. The power setting was 9 W, 450 mJ / 20 Hz with a water spray. The incision extended posteriorly from the distal area of #8 to the distal of #6 (Figure 5). Then a vertical releasing incision was made apically on #6, and a buccal flap was lifted (Figure 6). The infected area was then visualized. There was massive bone loss on the buccal apical aspect of the implant with a great deal of granulation tissue. The lack of mobility of the implant was confirmed.

The granulation tissue was ablated with the erbium laser in noncontact mode; the tip was a 1300-micron sapphire tip at a power of 8.4 W, 700 mJ / 12 Hz with a water spray (Figure 7). The removal of this granulation tissue produced a crater around the end of the implant. Next, the laser parameters were reduced to 3 W,
150 mJ / 20Hz and, with the same tip and water spray, the laser energy was aimed at the surface of the screw thread to obtain decontamination. Lastly, the laser was used to ablate the necrotic bone and to shape and remodel the site for GBR. A 1300-micron tip was used in noncontact with a power of 9 W, 450 mJ / 20 Hz and water spray (Figure 8). After lasing, the defect was filled with Bio-Oss® (Geistlich Pharma AG, Wolhusen, Switzerland), a bone substitute xenograft material, and covered Bio-Gide® (Geistlich Pharma AG), an absorbent bilayer membrane.

Figure 11: Primary closure with sutures

Figure 12: Ten-day postoperative view

Figure 13: One-and-a-half-month postoperative view

(Figures 9-10). The flap was sutured with 3-0 silk with careful attention paid to good primary closure (Figure 11). There are four important principles to keep in mind when performing GBR.10-56

- Fixation of the implant (the implant must be stable)
- There must be complete and passive soft tissue coverage
- There must be cortical stimulation by the material, and
- The vertical releasing incision should be as far as possible from the GBR site to enable good primary closure.

The purpose of GBR is to enable new bone formation, treat the anatomical defect, and improve the implant’s prognosis. The morphology of the defect is important for healing: the more walls of bone left, the better the implant reacts. Deficiency of blood supply causes failure; to improve the blood supply to the bone graft, decortication of the bone are performed.

Figure 14: One-and-a-half-month postoperative radiograph

Figure 15: Seven-month postoperative view

Figure 16: Seven-month postoperative radiograph

Postoperative Instructions

Clindamycin (150 mg x 50 tabs) was prescribed to prevent infection, and Motrin (800 mg x 15 tabs) for pain control. The patient was instructed to rinse with chlorhexidine 0.2% starting the next day for 2 weeks, three times a day, and was advised to maintain good oral hygiene.

Management of Complications and Follow-Up Care

The patient was examined the next day. She reported a moderate pain and moderate swelling of the cheek on the right side; but there was no tissue bleeding, the site was closed, and the flap was attaching with normal healing. Figure 12 depicts the 10-day postoperative view when the patient returned for inspection and suture removal. The swelling had resolved, there were no signs of fistula, and healing was progressing well. At six weeks, the soft tissue had healed over the bone and there were no bony projections (Figure 13), and the
radiograph showed good integration (Figure 14). The seven-month intraoral view (Figure 15) and the radiograph (Figure 16) show full healing. The prognosis is very good.

CONCLUSION
The Er:YAG laser can be used for decontamination of infected implant surfaces and has been shown to be effective and safe. The use of this laser wavelength for those procedures presents advantages over conventional methods such as reducing the patient’s discomfort, and allowing better visualization in the surgical site. In addition, postoperative effects, such as pain and swelling, are less pronounced. This laser is an invaluable tool for those procedures by simplifying treatment and offering patients faster and less stressful oral therapy.

AUTHOR BIOGRAPHIES
Dr. Avi Reyhanian graduated from the University of Bucharest, Romania in 1988. He then participated in a fellowship program at the Oral and Maxillofacial Department, Rambam Hospital, in Haifa, Israel. He currently practices general dentistry and oral surgery in Netanya, Israel. Dr. Reyhanian first incorporated dental lasers in his practice in early 2002, and currently uses Er-YAG, CO₂, and diode (830 nm) lasers. He has been performing periodontal surgery for the past 17 years (the last four with lasers) and has completed more than 100 cases of periodontal laser surgery. He is a member of the Academy of Laser Dentistry and the Israel Society of Dental Implantology. Dr. Reyhanian may be contacted by e-mail at: avi5000rey@gmail.com.

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Disclosure: Dr. Coluzzi is a lecturer for HOYA ConBio. He receives honoraria for those services.

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Upcoming issues of the Journal will feature case studies from the most recent recipients of Advanced Proficiency. These clinicians completed the two-year process by successfully presenting one of these cases at the Academy of Laser Dentistry's 2007 Annual Conference in Nashville, Tennessee. They are: Mary Lynn Smith, RDH; Charles Hoopingarner, DDS; and Steven Parker, BDS, LDS RCS, MFGDP.

In this issue, Mrs. Smith utilizes an Nd:YAG laser as part of the protocol for initial treatment of periodontal disease. She explains how the laser is integrated into the therapeutic appointment and demonstrates the wavelength’s benefits in helping to control the disease.

Dr. Hoopingarner performs gingival and osseous closed flap crown lengthening with an Er:YAG laser to help restore a bicuspid with a lingual cusp fracture that extended subgingivally. This case depicts the laser’s ability to ablate and contour both soft and hard tissue with precision and care, and ultimately to gain the necessary biologic width and tooth structure for a successful restoration.

These cases show how different laser wavelengths can be routinely employed in a variety of dental procedures to produce safe, efficient, and excellent clinical results.
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Nd:YAG Laser Use in Treatment of Moderate Chronic Periodontitis

Mary Lynn Smith, RDH, McPherson, Kansas


SYNOPSIS
This case report describes the use of an Nd:YAG laser as an integral component of the initial treatment of periodontal disease.

PRETREATMENT

A. Diagnostic Tests

1. Full Clinical Description
A healthy 47-year-old Hispanic male presented for examination. His chief complaint was the dark spot at the gingival margin of tooth #9 and limited chewing efficiency (Figure 1). His last dental visit was 6 months prior for an emergency extraction of tooth #19. He had never had any type of dental hygiene appointment. The patient speaks Spanish predominately, and communication was accomplished by the dentist translating information at specific times in each appointment.

During the initial hygiene appointment, the health history was reviewed and tissues were visually screened for signs of oral cancer. Comprehensive restorative, periodontal, and radiographic exams were completed. Micro-ultrasonic scaling, biofilm removal, and coronal polishing were performed. The patient was educated concerning his oral health and probable progression of untreated disease.

The patient was taking no medications and had no known allergies. He was missing nine teeth: #1, 16, 17, 19, 20, 25, 26, 30, and 32. Decay was noted on teeth #3, 15, and 18. Significant fractures were noted on tooth #18 as well. The occlusion was Angle’s classification I with normal TMJ function. Supragingival calculus and gingival inflammation indicated possible periodontal disease. Complete periodontal charting revealed periodontal probing depths of 2-7 mm. Areas of recession exposing 1 to 4 mm of root surface were present. Furcations and mobility were also noted on the molars.

2. Radiographic Examination
A full-mouth series with 4 vertical bitewings and 14 periapical films was taken to further evaluate bone loss and carious lesions (Figure 2).

Decay was noted on teeth #3 and 18. Decay on #15 was not detected radiographically. There was moderate generalized horizontal bone loss with areas of severe vertical bone loss on posterior teeth. Areas of particular concern were teeth #2, 15, 18, and 31. These teeth were diagnosed as hopeless due to the periodontal involvement and/or decay present and were scheduled for extraction. Generalized moderate-to-heavy calculus was noted on the radiographs.
3. Soft Tissue Status
Tissues appeared inflamed and irritated with the presence of plaque and calculus. A complete six-point periodontal probing was performed with 7 mm as the greatest pocket depth. Generalized bleeding was evident and moderate-to-heavy subgingival calculus was present in posterior areas, as well as supragingivally on the lower anterior teeth. Gingival recession of 1-2 mm was noted on teeth #2, 3, 4, 5, 12, 13, 14, and 15 buccal surfaces and 1-4 mm on lingual surfaces of teeth #2, 3, 4, 14, 15, 18, 23, 24, 27, 28, 29, 31. Mobility of class I was detected on tooth #14 and class II on #2, 15, 18, and 31. Class I furcations were found on #2, 3, 14, 15, 18, and 31, and class II furcations on #2, 15, 18, and 31 (Figure 3). A statistical summary of overall periodontal health showed 36 hemorrhaging sites upon probing, 45 periodontal pockets of 4 mm or greater, and 19 teeth exhibiting beyond-normal limits in pocketing. (This summary excludes teeth #2, 15, 18, and 31 which were diagnosed as hopeless.)

The oral cancer screening was within normal limits.

4. Hard Tissue Status
- Missing teeth were #1, 16, 17, 19, 20, 25, 26, 30, and 32
- All other teeth were vital
- Occlusion was Angle’s Class I
- Decay was present on teeth #3 DL, #15 O, and #18 DOL with fractures noted on the mesial, lingual and distal aspects
- Limited mastication was present due to missing posterior teeth.

5. Other Tests
TMJ was normal.

B. Diagnosis and Treatment Plan
1. Diagnoses
- Provisional diagnosis included chronic periodontitis with poor prognosis of molars.
- The doctor’s final diagnosis was stated as severe generalized chronic periodontitis. Carious lesions were present on teeth #3 DL, #15 O, #18 DOL, with significant fractures on #18 MLD.

2. Treatment Plan Outline
a. Restorative treatment to include:
   - restoration of tooth #3 with a distolingual composite
   - simple extractions of teeth #2, 15, 18, and 31
   - replacement of teeth #19, 20, 25, 26, and 30 with a partial denture or implants.

b. Active phase-I periodontal infection therapy to include five periodontal infection therapy appointments, one hour each and scheduled approximately a week apart:
   - assessment of patient’s plaque management, refining techniques and continuing motivation for thorough daily care
   - micro-ultrasonic instrumentation and hand instrumentation for biofilm and calculus removal
   - laser soft tissue decontamination and superficial coagulation
   - intraoral photographs.

c. Six-week post-therapy re-infection assessment appointment to include:
   - one appointment for 30 minutes:
   - visual evaluation of tissue rehabilitation
   - assessment of patient’s plaque management, refining techniques and continuing motivation for thorough daily care
   - intraoral photographs
   - micro-ultrasonic biofilm removal at gingival third of tooth
   - probing and sulcular instrumentation is avoided in order to allow undisturbed maturation of connective tissue at the base of the pocket.

d. Twelve-week post-therapy appointment to include:
   - health history review
   - oral cancer screening
   - periodontal charting to assess rehabilitation
   - assessment of patient’s plaque management, refining techniques and continuing motivation for thorough daily care
   - micro-ultrasonic instrumentation for full-mouth bacterial decontamination and scaling as needed
   - coronal polishing
   - laser decontamination of unresolved areas
   - intraoral photos
   - determination of recare interval.

3. Indications for Treatment
Treatment is indicated to halt the periodontal destruction and rehabilitate the affected tissues. Periodontal infection therapy must include removal of biofilm and calculus from the root surfaces through scaling. The Nd:YAG laser furthers decontamination of the pocket by addressing the periodontal pocket wall. The 1,064-nm laser wavelength is highly absorbed in melanin and hemoglobin. Both of these chromophores are present in inflammatory tissue. Laser-tissue interaction reduces pathogens prior to extraction, teeth diagnosed as hopeless were not considered for therapy. There were no contraindications for this patient to receive Nd:YAG laser-assisted treatment of periodontal disease. Laser safety precautions were followed for protection of the patient and clinician.

The energy from the Nd:YAG laser must be directed toward the soft tissue and away from the tooth and bone.
5. Treatment Alternatives
Treatment alternatives included:
• No treatment and progression of disease, eventual tooth loss and systemic impact
• Conventional scaling and root planning
• Placement of localized antimicrobials or antibiotics with possible reactions
• Periodontal surgery.

6. Informed Consent
After being educated in the progression of untreated periodontal disease and treatment options, the patient gave verbal and written consent to proceed with the planned therapy. This is documented in the patient's record.

TREATMENT

A. Restorative Treatment Objective
Teeth #2, 15, 18, and 31 were extracted prior to phase I active periodontal infection therapy. Tooth #3 caries removal and composite restoration was placed after completion of therapy per the patient’s request.

B. Periodontal Treatment Objective
The treatment objectives are to halt the destruction of the periodontium due to disease processes. Laser-assisted periodontal treatment will reduce bacterial load in the periodontal pocket wall, eliminating the related inflammatory response by the body. The Nd:YAG laser wavelength is well absorbed in pigmented and hemoglobin-rich inflamed tissue. Signs of healing, such as decreased probing depths, elimination of hemorrhaging, and normal tissue coloration and texture, are desired. The appointments are designed to allow patient-customized education in specific daily plaque management techniques, ensuring maximum rehabilitation of the tissues. Beginning with the most infected teeth, each appointment will address three to four teeth for debridement of root surfaces through scaling, followed by tissue decontamination and superficial coagulation through lasing. At the subsequent appointment, approximately 7 to 10 days later, a different group of teeth will be debrided and tissues lased. The previously treated area will be revisited for ultrasonic biofilm removal from tooth surfaces and laser decontamination of tissues. Instrumentation with the ultrasonic is concentrated on the cervical area of tooth structure and the fiber is calibrated to 1 mm less than the previous application. This continues the reduction of bacterial load and enhances the body’s healing response. It also allows reinforcement of behavior modification in daily plaque management.

C. Laser Operating Parameters
A free-running pulsed Nd:YAG laser (PulseMaster 600 IQ, American Dental Technologies, Corpus Christi, Texas) with a 1064-nm emission wavelength was used with a 400-micron contact fiber. For bacterial reduction, the laser parameters were 30 mJ and 60 Hz, average power of 1.8 Watts for approximately 40 seconds per site; for superficial coagulation, the settings were 100 mJ and 20 Hz, with an average power of 2.0 Watts for approximately 20 seconds per site. The total laser emission time for the five sessions of periodontal infection therapy was 155 minutes.

D. Treatment Delivery Sequence
The treatment delivery sequence at each therapeutic appointment included:
• review of health history
• plaque management assessment and instruction
• anesthetic as needed
• topical anesthetic administered at the gingival margin and subgingivally. A compounded preparation called TAC (20% lidocaine, 4% tetracaine, and 2% phenylephrine) was used
• local anesthetic of 2% lidocaine with epinephrine 1:100,000 was administered for more profound anesthesia
• infiltration with 4% articaine with epinephrine 1:100,000 was administered when a full block was not necessary
• micro-ultrasonic and hand instrument debridement of root surfaces
• laser decontamination and superficial coagulation
• postoperative care instructions given.

Laser safety measures included:
• use of 1,064-nm laser wavelength protective eyewear by all operator personnel
• use of 0.1-micron filtration masks
• environment secured to limit access
• laser-in-use warning sign placed
• reflective surfaces minimized
• high-volume evacuation utilized for plume control and to cool the tissue.

Chart documentation included laser and wavelength used, fiber size and type, operating parameters, and emission time.

The laser fiber was cleaved and the laser test-fired. The fiber was calibrated to 1 mm less than the pocket depth (Figure 4). With the fiber remaining in constant contact with the internal pocket tissue and in constant motion, treatment began at the top of the pocket and progressed apically, moving the fiber vertically and horizontally until the

Figure 4: Laser fiber is calibrated to 1 mm less than the pocket depth
calibrated depth was reached. The fiber was always directed away from the root surface and toward the target tissue. Accumulated debris was wiped from the fiber and a proper cleave maintained (Figure 5). Figure 6 shows the laser technique on tooth #3, which is featured in this case. The amount of lasing time was influenced by tissue interaction, extent of disease, and depth of the pocket. When fresh bleeding was visible, the laser procedure was deemed complete for that site (Figure 7). High-volume suction was present to eliminate the plume and cool the tissue.

Several figures demonstrate the typical treatment protocol in two different areas of the mouth.

Figure 8a shows initial mesiobuccal pocket on tooth #14, 8b shows the laser treatment, and 8c shows the immediate postoperative coagulation.

Figure 9a shows the mesiolingual pocket of tooth #28, 9b shows the laser treatment, and 9c shows the immediate postoperative coagulation.

E. Postoperative Instructions
Postoperative instructions were given in verbal and written form. The patient was instructed to avoid (for the first 24 hours) acidic, rough, or crunchy foods. Normal eating
could resume following that period. Avoidance of seeds, husks, and other foods that may lodge between the gingiva and tooth was recommended for a week. In the areas lased, subgingival flossing and the small Sulcbrush® (Sulcbrush Inc., Niagara Falls, N.Y.) were to be avoided for several days. Use of an ultrasoft toothbrush and supragingival cleaning was recommended. All other areas were to be cleaned as usual. If discomfort were to occur, the patient was instructed to use warm salt water rinses and over-the-counter pain medication. The patient was informed that the most important aspect of the therapy was the healing process, and minimizing plaque at the gingival margin was critical in preventing re-infection.

F. Complications

The patient experienced cold sensitivity. He was prescribed 1.1% neutral sodium fluoride with potassium nitrate for daily use. It was effective and he had no other complications during or after the laser treatments.

G. Prognosis

Prognosis overall is good as long as the patient conforms to good oral hygiene and recommended intervals for professional supportive maintenance visits. Periodontally, teeth #3 and 14 will be monitored for continued improvement. Restorative treatment is needed to reduce functional stresses on existing teeth.

H. Documentation

All treatment and related information was recorded in the patient’s treatment record.

FOLLOW-UP CARE

A. Assessment of Treatment Outcomes

The patient was assessed at 1 week, 6 weeks, 12 weeks, and 6 months following active phase-I periodontal infection therapy. Periodontal charts show comparative data of initial state to 12 weeks post-therapy as well as 6 months post-therapy. Percentage of improvement is seen with 92% in bleeding reduction, 80% in pocket site reduction, and 68% fewer teeth exhibiting periodontal pocketing.

The one-week examination revealed that the tissues were healing and the patient’s skill in plaque management was improving. For example, Figure 10a shows the one-week view of tooth #14, and Figure 10b shows the one-week view of tooth #28.

Figure 10a: One-week postoperative view of tooth #14

Figure 10b: One-week postoperative view of tooth #28

Figure 10: One-week postoperative views

Figure 11: Twelve-week postoperative periodontal probing chart

Figure 11: Twelve-week postoperative periodontal probing chart

Figure 12a: Tooth #14

Figure 12b: Tooth #28

Figure 12: Twelve-week postoperative probing
Six-week post-therapy reinfection assessment appointment included:
- confirmation that the patient is maintaining plaque control.
- tissues are continuing to improve.
- health history review
- visual evaluation of tissue rehabilitation
- assessment of the patient’s plaque management, refining techniques and continuing motivation for thorough daily care
- intraoral photographs
- micro-ultrasonic biofilm removal at gingival third of tooth
- probing and sulcular instrumentation was avoided in order to allow undisturbed maturation of connective tissue at the base of the pocket.

Twelve-week post-therapy appointment:
Overall, a marked improvement was seen in periodontal health, such as decreased probing depths, decreased bleeding on probing, normal tissue coloration, firm texture, and lack of mobility. Teeth #3 and 14 need continued refinement of plaque management and further therapy. This appointment included:
- health history review
- oral cancer screening
- six-point pocket and hemorrhaging periodontal charting to assess rehabilitation (Figure 11)
- assessment of the patient’s plaque management, refining techniques and continuing motivation for thorough daily care
- micro-ultrasonic instrumentation for full-mouth bacterial decontamination and hand instrumentation as needed
- coronal polishing
- laser decontamination of appropriate areas
- determination of recare interval at 12 weeks.

The previously mentioned Nd:YAG laser was used with a setting for decontamination of 30 mJ and 60 Hz, 1.8 Watts average power, and additional hemostasis application for teeth #3 and 14 at 100 mJ and 20 Hz, 2.0 Watts delivered with a 400-micron contact fiber for 7 minutes total emission time. Oral hygiene instructions were reviewed. Continued use of daily fluoride as caries prevention was recommended. A 12-week supportive periodontal therapy appointment was scheduled. Short-term follow-up for tooth #14 is shown in Figure 12a and for tooth #28 in Figure 12b.

Six-month post-therapy appointment:
Tissue health is maintaining very well. Tooth #3 is continuing to improve while #14 remains an area of concern. Periodontal chartings compare the initial, 12-week, and...
6-month periodontal status. The 6-month therapeutic appointment included:

- health history review
- oral cancer screening
- six-point periodontal charting (Figure 13)
- assessment of the patient’s plaque management, refining techniques and continuing motivation for thorough daily care; instructions to continue daily fluoride applications
- micro-ultrasonic instrumentation for full-mouth bacterial decontamination and hand instrumentation as needed
- coronal polishing
- laser decontamination of appropriate areas
- instruction to continue 12-week maintenance interval.

The previously mentioned Nd:YAG laser was used with a 400-micron fiber and parameters of 30 Hz, 60 mJ, average power of 1.8 Watts for decontamination. Hemostatic assistance was accomplished with 100 mJ, 20 Hz, average power of 2.0 Watts applied to sites of tooth #14 due to increased inflammation. Emission time totaled 8 minutes. Long-term follow-up is illustrated: Figure 14a shows the 6-month probing of tooth #14 and 14b shows tooth #28.

### Table 1: Results of Laser-Assisted Therapy

<table>
<thead>
<tr>
<th>Treatment Assessment Interval</th>
<th>Number of Sites with Bleeding on Probing</th>
<th>Number of Sites with Periodontal Pockets 4 mm or Greater</th>
<th>Number of Teeth with Beyond-Normal Periodontal Pocketing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>36</td>
<td>45</td>
<td>19 of 19</td>
</tr>
<tr>
<td>12 Weeks</td>
<td>3</td>
<td>9</td>
<td>6 of 19</td>
</tr>
<tr>
<td>6 Months</td>
<td>7</td>
<td>4</td>
<td>2 of 19</td>
</tr>
<tr>
<td>Rate of Improvement After 6 Months</td>
<td>81%</td>
<td>91%</td>
<td>90%</td>
</tr>
</tbody>
</table>

B. Complications
Continued daily use of fluoride was recommended for caries prevention. The patient had no soft or hard tissue damage and was pleased with the results from the laser.

C. Long-Term Results
At 12 weeks post-therapy there was marked improvement. Hemorrhaging sites were reduced by 92%, number of perio sites by 80%, and number of teeth affected by 68%. At 6 months post-therapy, the patient had an increase in hemorrhaging sites but other improvements continued. The patient’s health compared to his initial state showed improvements of 81% in hemorrhaging, 91% in perio sites, and 90% number of teeth affected (Table 1). Figures 15a and 15b show the comparison of tissues initially and at 6 months post-therapy.

D. Long-Term Prognosis
The patient was compliant with all treatment aspects and a good prognosis exists. It will require conformity to good oral hygiene and continued professional supportive maintenance visits at 12-week intervals. Periodontally, teeth #3 and 14 will be monitored for continued improvement.

Adjustment of the maintenance interval and adjunctive use of Arestin® (OraPharma Inc., Warminster, Pa.) are possible. In the case of acute and rapid progression, surgical intervention or extraction may be indicated. Replacement of missing mandibular teeth will be very important to alleviate excessive functional stress on existing teeth. If a partial denture is chosen rather than implants, caries prevention and periodontal stability of supporting teeth will be a concern. Caries prevention strategy includes effective daily plaque management, daily use of fluoride, and reduced acid sources in diet, as well as consistent professional care. An oral irrigator for daily use would be beneficial for all teeth present.

### AUTHOR BIOGRAPHY
Mary Lynn Smith is a registered dental hygienist, working clinically for more than 12 years. She achieved her Standard Proficiency in the Nd:YAG (1,064-nm) and diode (810-nm) wavelengths in 2003, and completed her Advanced Proficiency in the Nd:YAG in 2007. Mary Lynn has contributed to the dental community through articles and speaking to fellow hygienists on care of implants, periodontal therapies, and laser-assisted hygiene techniques and principles. She currently resides in McPherson, Kansas and is employed by Dr. Jon Julian, DDS. Mrs. Smith may be contacted by e-mail at mlsrdh@swbell.net.

**Disclosure:** Mrs. Smith has no commercial relationships relative to this case presentation.
Treatment of a Subcrestal Tooth Fracture with the Er:YAG Laser

Charles R. Hoopingarner, DDS, Houston, Texas


SYNOPSIS

This article describes gingival and osseous closed flap crown lengthening with an Er:YAG laser to help restore a bicuspid with a lingual cusp fracture that extends subgingivally.

PRETREATMENT

A. Outline of Case

1. Full Clinical Description

A 62-year-old Caucasian male presented with severe pain on chewing in the area of tooth #13. Figure 1 shows a deep vertical fracture of an existing MOD ceramic onlay and the underlying palatal cusp. He had complained of occasional biting sensitivity at two previous recare visits. No definitive findings were made at either visit. At that time a vital pulp test and radiographic evaluation were performed, and a minor occlusal adjustment was made. He had been an 11-year patient in the practice and maintained a very good level of dental health, and it was expected he would continue to be followed in our office. A recare evaluation and prophylaxis had been performed 3 months prior to the onset of the obvious fracture and extreme pain with no other pathologic dental or significant periodontal findings. He is allergic to penicillin and on presentation his vital signs were within normal limits (blood pressure 115/68, pulse 64). He was taking no medications and had no further contributing medical history. He has a well-restored Class I dental occlusion and has cast restorations on teeth #4, 15, 29, and 30. He had existing intracoronal restorations in teeth #2, 3, 6, 12, 14, 18, 19, 20, 28, and 31.

2. Radiographic Examination

Previous panoramic X-ray showed no significant bone loss or any lesions present. A periapical X-ray did not show apical pathology or vertical bone loss present (Figure 2).

3. Soft Tissue Status

An oral cancer screen and periodontal probing had been performed within a three-month period. When done, no soft tissue lesions were present, and no pocket depth measurements were in excess of 4 mm, as shown in Figure 3. (As is the custom in our office, no pocket depths less than 4 mm were recorded.)

Tooth #13 was probed and there were no readings in excess of 3 mm except along the border of the fractured segment. There was periodontal attachment present on the fractured segment and a 4-5 mm measurement from the gingival crest to the remaining attachment.
4. Hard Tissue Status
All bone levels and ridge topography had historically been within acceptable limits. The area around tooth #13 showed no vertical bone loss. The palatal cusp of tooth #13 had fractured below the attachment level and after removal would show a termination at the osseous crest. There were signs of bruxism present and the patient reported that he was wearing a nighttime protective appliance that had been prescribed many years prior to this presentation. The tooth tested vital to air spray stimulation and it was necessary to use injected local anesthesia to fully evaluate the extent of the fracture.

5. Other Tests
TMJ evaluation showed normal range of motion and no joint sounds were present.

B. Diagnosis and Treatment Plan
1. Provisional Diagnosis
A provisional diagnosis of vertical fracture of the palatal cusp of tooth #13 was made. It was thought that the fracture would extend to the osseous crest in a limited area, making impression-taking difficult. The position of the osseous crest obviated a consideration of biologic width issues. There was no pulpal exposure evident.

2. Final Diagnosis
A final diagnosis of vertical fracture of the palatal cusp of tooth #13 was made. Figure 4 shows the fragment being removed. The extent of the fracture was limited to areas coronal to the periodontal attachment except for an approximate 3-mm linear area in a readily accessible area of the palatal osseous crest, as seen in Figure 5. Since the fracture was observed to terminate at the osseous crest, any restoration would impinge on the biologic width necessary to maintain a healthy tooth support system.

3. Treatment Plan Outline
The objective was to restore the patient’s tooth with a bonded ceramic restoration that would restore nearly ideal tooth form and permit proper attachment levels without invasion of the biologic width necessary to maintain periodontal health. Initially the tooth would be prepared to allow for coverage of the fractured areas. The preparation would be as conservative as possible as utilization of a bonded restoration did not require apical preparation extension for the purpose of retention. This procedure would be done with conventional rotary instruments. If the fractured root structure could be smoothed to allow placement of a margin at a more coronal level, that would become a part of the procedure.

The 2940-nm Er:YAG laser would be used for two procedures. The first would be to contour the soft tissue in a manner that would leave the margins of the restoration at the gingival crest. The preparation would be as conservative as possible as utilization of a bonded restoration did not require apical preparation extension for the purpose of retention. This procedure would be done with conventional rotary instruments. If the fractured root structure could be smoothed to allow placement of a margin at a more coronal level, that would become a part of the procedure.

The second procedure would be to remove osseous tissue to a level 3 mm below the intended margin and bevel the bone to a normal contour.

4. Indications
As the 2940-nm Er:YAG laser wavelength is highly absorbed by both water and hydroxyapatite, it can be used to both contour the soft tissue and lower the bone level where indicated to establish a healthy attachment. With a closed flap technique, the postoperative recovery is shortened and the patient discomfort level is minimized. With this approach impressions could be taken at the time of surgery and the restoration placed within the time frame of a normal delivery.

5. Contraindications
There were no contraindications for performing this procedure.

6. Precautions
During the initial gingival recontour it is necessary to carefully consider the desired outcome after healing. The soft tissue ablation should be performed by angling the tip in a manner to avoid damaging tooth structure. As the final contours are approached, care must be taken to avoid interacting with the bone prior to the initiation of water spray. Rehearsal of the bone ablating stroke is often necessary as the water spray can impair direct visualization.

7. Treatment Alternatives
Conventional flap surgery with gingival sculpting using scalpel technique and bone recontouring with rotary instruments or chisels is an alternative. Tooth extraction is an alternative.

8. Informed Consent
After a description of advantages, possible complications, and treatment alternatives were discussed, and all the patient’s questions were
answered, the patient’s verbal and written informed consent was obtained.

**TREATMENT**

**A. Treatment Objectives**
The objective is to remove the fractured fragment, prepare the tooth, smooth the root surface, contour the gingiva, take an accurate impression, recontour the osseous crest to allow for proper biologic width formation, and place a well-formed provisional restoration so that bonded cementation could occur in a timely fashion. The Er:YAG laser will be used for recontouring both the gingival tissues and the osseous tissue.

**B. Laser Operating Parameters**
Laser: Er:YAG (DELight, HOYA ConBio, Fremont, Calif.):
- Delivery system: Fiber-optic system consisting of varying quartz tips: 600-micron for initial tissue ablation, 400-micron for osseous recontouring, and 1200 x 300-micron chisel tip for tissue and osseous beveling and smoothing
- Wavelength: 2940 nm
- Mode: Free-running pulsed
- Pulse width: 300 microseconds
- Power: 1.5 Watts (30 Hz and 50 mJ)
- Beam Diameter: Varied, 400 to 600 microns using focused and defocused patterns
- Repetition rate: 30 Hz
- Continuous air (reduced volume and water spray for osseous procedures, and air only for soft tissue)

**Laser settings:**
- Soft tissue ablation: 30 Hz and 50 mJ, air cooling and no water
- Osseous recontouring: 30 Hz and 50 mJ with air and water spray
- Tips were used in both light contact and defocused modes.

**C. Treatment Delivery Sequence**
Pretreatment: The operatory was secured and the laser warning sign was posted. The laser unit was properly placed and connected to an air supply. Safety glasses with 4+ optical density for the 2940-nm laser wavelength that met ANSI standards Z136.1 and Z136.3 were used. All shiny reflective objects were removed. The operatory was set up and supplied according to the standard for a restorative and a surgical procedure. Charting and radiographs were visible to the operator. The procedure was reviewed with staff in the morning report meeting. Prior to administration of anesthesia, the treatment was reviewed with the patient and informed consent was confirmed. The patient was properly draped and approximately 1.5 cc prilocaine 4% 1:200,000 epinephrine was distributed by infiltration in the maxillary premolar segment.

The distance from the fracture margin to the osseous crest was determined to be less than 1 mm. The probing of this depth is shown in Figure 7. It was felt that a margin could be placed 1 mm coronal to the extent of the fracture if the root were shaped and polished using rotary instruments and curettes. After this procedure was accomplished, there was still a distance of only 2 mm from the intended margin to the osseous crest. With copious water spray, a 400-micron tip, and the same energy settings (30 Hz and 50 mJ), the bone was ablated to allow for a distance of slightly more than 3 mm from the osseous crest to the intended preparation margin. This was done with short, noncontact strokes, with care being taken to avoid scarring the tooth. The 3-mm...
sleeve on the 400-micron tip was used as a guide, as shown in Figure 8. Had this convenient marking apparatus not been available, ink or stopper material could have been used as a measuring guide. With the 600-micron tip and the chisel tip, the bone was beveled to approximate a normal crestal contour. Total exposure time for the osseous segment was less than 7 minutes. This gave a total exposure time of less than 10 minutes.

With the depth of the fracture area left untouched where the root was smoothed, the tooth was prepared in a conservative manner to receive a ceramic restoration (Empress®, Ivoclar Vivadent Inc., Amherst, N.Y.), as shown in Figure 9. Figure 10 shows the confirmation of the new osseous level to be just over 3 mm from the intended preparation margin. A deep chamfer/shoulder margin was then placed in that area, with care being taken to maintain the desired crest-to-margin distance, and the preparation was completed (Figure 11).

With care taken to operate in a noncontact mode, gingival hemorrhage was greatly reduced. The final impression was obtained during the operative visit. The crisp, clear impression again confirmed the osseous crest depth (Figure 12).

A provisional restoration of temporary crown and bridge material (Integrity™, Dentsply, York, Pa.), shown in Figure 13, was placed to maintain tissue contour. The provisional was evaluated at 48 hours and no signs of infection or significant inflammation were present. Due to patient travel requirements, it was necessary to bond the final restoration just 10 days after preparation. There was minimal soft tissue invasion in the deep marginal area (Figure 14) which was easily removed with a 3% hydrogen peroxide scrub. The restoration was bonded with a total etch protocol using a single-component adhesive (Optibond® Solo Plus™, Kerr Corporation, Orange, Calif.) as a bonding agent and an adhesive resin (Nexus II, Kerr Corporation) as a cement. This was performed in light-cure-only mode, and cured for 10 seconds at all four interproximal corners and 20 seconds on the buccal, occlusal, and palatal surfaces (Figure 15).

D. Postoperative Instructions

The patient was told to avoid foods warmer than room temperature for 48 hours and then begin hot saline mouth rinses. The area was to be cleaned with hydrogen peroxide on cotton tip applicators for the first 48 hours. After the first postoperative visit, the patient was cleared for normal hygiene procedures.
which included brushing with an ultrasoft brush dipped in hot water. He was told not to floss around the provisional restoration and to avoid sticky foods in that area. Emergency care contact numbers were given. No narcotic analgesics were prescribed and the patient was instructed to use over-the-counter ibuprofen if necessary.

E. Complications
There was slight soft tissue invasion under the provisional restoration. This was removed with a 3% hydrogen peroxide scrub. The shade of the restoration was a little opaque but well within the patient’s acceptable expectation limits.

F. Prognosis
The prognosis for maintenance of the restoration is excellent. The tissue appeared to be healing nicely, giving an expectation of an excellent prognosis. The prognosis for continued pulpal vitality was still somewhat guarded.

G. Treatment Records
All appropriate details described above were entered into the patient’s record.

FOLLOW-UP CARE
A. Assessment of Treatment Outcome
The patient was very pleased with the treatment outcome, especially since he was seen on an emergency basis and treatment was completed in a short time frame to meet his travel schedule. He reported no postoperative pain and the tissues showed no sign of inflammation or inappropriate pocket depth. No deep probing was indicated for three months postoperatively.

B. Complications
The patient reported no postoperative complications.

C. Long-Term Results
At 3 months the restoration showed no signs of failure and had intact margins. The tissues were maintaining a good level of health with a palatal probing depth of 2 mm (Figure 16). The periapical radiograph (Figure 17) demonstrated normal tissue.

D. Long-Term Prognosis
Because of the biocompatibility of the pressed ceramic restoration and the exact treatment planning of the attachment levels, the long-term tissue prognosis remains excellent.

AUTHOR BIOGRAPHY
Dr. Charles Hoopingarner attended the University of Texas Health Science Center at Houston (UTHSCH) Dental Branch, graduating with a DDS in 1973. He has maintained a private practice in Houston, Texas since 1973. He was an adjunct associate professor in anatomical sciences at UTHSCH Dental Branch for 11 years. Currently he is adjunct clinical faculty in the Restorative Dentistry Department at UTHSCH and has been a clinical instructor at the Las Vegas Institute for Advanced Dental Studies since 1997, teaching Advanced Anterior Aesthetics and Comprehensive Aesthetic Reconstruction and Laser Dentistry. Dr. Hoopingarner is a member of the Academy of Laser Dentistry (ALD) and has used dental lasers of various wavelengths as integral parts of his patient care delivery system for the last 10 years. He holds Advanced and Standard Proficiency certification from the ALD and has lectured internationally on the safety and use of laser technology in the dental practice. He may be contacted by e-mail at choop@swbell.net.

Disclosure: Dr. Hoopingarner has no direct financial or ownership positions with commercial companies relative to this case presentation. He has received honoraria and expenses from HOYA ConBio to present material on laser dentistry.
In their article on Er-YAG laser-assisted implant peri-apical lesion therapy (135-141), Dr. Avi Reyhanian and Dr. Donald Coluzzi mention the bactericidal potential of laser irradiation of implant surfaces. The notion of utilizing laser energy to reduce surface bacteria on intraoral implants as a means to help ensure successful osseointegration and reduce the incidence of peri-implantitis has been studied by a number of researchers investigating a variety of wavelengths, including excimer, diode, Nd:YAG, erbium, and carbon dioxide lasers. Abstracts from a sampling of published papers representing various wavelengths appear below.

Most researchers to date have investigated the antimicrobial effect, primarily due to heat generated by various lasers, on implant surfaces in *in vitro* experiments. Heinrich and colleagues take a different approach: use a KrF excimer (248 nm) laser to promote mucosal adhesion as a biological barrier against bacterial infection. Another group (Dörtbudak et al.) studied the effects of “soft” diode laser exposure on implants in patients.

Overall, results are mixed. Certain lasers do appear to have bactericidal potential on selected microorganisms on certain types of implants under certain conditions. Questions regarding the relative efficacy of laser vs. conventional treatment remain, as do concerns related to potential alteration of implant surface morphology, thermal damage to adjacent tissues, and inability to reestablish the biocompatibility of contaminated surfaces. Nevertheless, the potential for laser application in promoting long-term implant success via bacterial reduction exists. Further study is warranted, especially to determine effectiveness and safety in a clinical environment, with special emphasis placed on appropriate parameter settings and duration of laser exposure.

For U.S. readers, no laser has been cleared by the U.S. Food and Drug Administration for “decontaminating” or inducing bactericidal effects on intraoral implants.

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.
Concerning dental implant systems, a main problem is the adhesion of peri-implant mucosa in the cervical region. The aim of the present study was to use a laser for modifying titanium implants to promote mucosal adhesion, which is indispensable as a biological barrier against bacterial infection. By the use of a KrF excimer laser, it was possible to induce a holey structure on the polished area of the implant surface, which was analysed by a scanning electron microscope. In addition, the attachment of fibroblast cells to the created structures was investigated with the aid of an environmental scanning electron microscope. It turned out that the cells preferentially attach to the holey structure. Thereby, the cells form bridges inside, leading to a complete covering of the hole. In this way, a more effective biological barrier against bacteria can be created.

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Peri-implantitis is considered to be a multifactorial process involving bacterial contamination of the implant surface. A previous study demonstrated that a combination of toluidine blue O (100 microgram/ml) and irradiation with a diode soft laser with a wavelength of 905 nm results in an elimination of Porphyromonas gingivalis (P. gingivalis), Prevotella intermedia (P. intermedia), and Actinobacillus actinomycetemcomitans (A. actinomycetemcomitans) on different implant surfaces (machined, plasma-flame-sprayed, etched, hydroxyapatite-coated). The aim of this study was to examine the laser effect in vivo. In 15 patients with IMZ implants who showed clinical and radiographic signs of peri-implantitis, toluidine blue O was applied to the implant surface for 1 min and the surface was then irradiated with a diode soft laser with a wavelength of 690 nm for 60 s. Bacterial samples were taken before and after application of the dye and after lasing. The cultures were evaluated semiquantitatively for A. actinomycetemcomitans, P. gingivalis, and P. intermedia. It was found that the combined treatment reduced the bacterial counts by 2 log steps on average. The application of TBO and laser resulted in a significant reduction (P < 0.0001) of the initial values in all 3 groups of bacteria. Complete elimination of bacteria was not achieved.

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ANTIMICROBIAL EFFICACY OF SEMICONDUCTOR LASER IRRADIATION ON IMPLANT SURFACES

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Int J Maxillofac Implants 2003;18(5):706-711

Purpose: This study was conducted to investigate the antimicrobial effect of an 809-nm semiconductor laser on common dental implant surfaces. Materials and Methods: Sandblasted and acid-etched (SA), plasma-sprayed (TPS), and hydroxyapatite-coated (HA) titanium disks were incubated with a suspension of *S. sanguinis* (ATCC 10556) and subsequently irradiated with a gallium-aluminum-arsenide (GaAlAs) laser using a 600-microm optical fiber with a power output of 0.5 to 2.5 W, corresponding to power densities of 176.9 to 884.6 W/cm². Bacterial reduction was calculated by counting colony-forming units on blood agar plates. Cell numbers were compared to untreated control samples and to samples treated with chlorhexidine digluconate (CHX). Heat development during irradiation of the implants placed in bone blocks was visualized by means of shortwave thermography. Results: In TPS and SA specimens, laser irradiation led to a significant bacterial reduction at all power settings. In an energy-dependent manner, the number of viable bacteria was reduced by 45.0% to 99.4% in TPS specimens and 57.6% to 99.9% in SA specimens. On HA-coated disks, a significant bacterial kill was achieved at 2.0 W (98.2%) and 2.5 W (99.3%) only (t test, P < .05). For specimens treated with CHX, the bacterial counts were reduced by 99.99% in TPS and HA-coated samples and by 99.89% in SA samples. Discussion: The results of the study indicate that the 809-nm semiconductor laser is capable of decontaminating implant surfaces. Surface characteristics determine the necessary power density to achieve a sufficient bactericidal effect. The bactericidal effect, however, was lower than that achieved by a 1-minute treatment with 0.2% CHX. The rapid heat generation during laser irradiation requires special consideration of thermal damage to adjacent tissues. Conclusion: No obvious advantage of semiconductor laser treatment over conventional methods of disinfection could be detected in vitro.

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ELIMINATION OF BACTERIA ON DIFFERENT IMPLANT SURFACES THROUGH PHOTOSENSITIZATION AND SOFT LASER: AN IN VITRO STUDY

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University of Vienna, Vienna, Austria


Microbiologic examinations of implants have shown that certain microorganisms described as periodontal pathogens may have an influence on the development and the progression of peri-implant disease. This experimental study aimed to examine the bactericidal effect of irradiation with a soft laser on bacteria associated with peri-implantitis following exposure to a photosensitizing substance. Platelets made of commercially pure titanium, either with a machined surface or with a hydroxyapatite or plasma-flame-sprayed surface or with a corundumblasted and etched surface, were incubated with a pure suspension of *Actinobacillus actinomycetemcomitans* or *Porphyromonas gingivalis* or *Prevotella intermedia*. The surfaces were then treated with a toluidine blue solution and irradiated with a diode soft laser with a wavelength of 905 nm for 1 min. None of the smears obtained from the thus-treated surfaces showed bacterial growth, whereas the smears obtained from surfaces that had been subjected to only one type of treatment showed unchanged growth of every target organism tested (P < 0.0006). Electron microscopic inspection of the thus-treated platelets revealed that combined dye/laser treatment resulted in the destruction of bacterial cells. The present in vitro results indicate that lethal photosensitization may be of use for treatment of peri-implantitis.

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EFFECTS OF THE ND:YAG DENTAL LASER ON PLASMA-SPRAYED AND HYDROXYAPATITE-COATED TITANIUM DENTAL IMPLANTS: SURFACE ALTERATION AND ATTEMPTED STERILIZATION

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The Nd:YAG dental laser has been recommended for a number of applications, including the decontamination or sterilization of surfaces of dental implants that are diseased or failing. The effects of laser irradiation in vitro (1) on the surface properties of plasma-sprayed titanium and plasma-sprayed hydroxyapatite-coated titanium dental implants, and (2) on the potential to sterilize those surfaces after contamination with spores of Bacillus subtilis have been examined. Surface effects were examined by scanning electron microscopy, energy dispersive spectroscopy, and X-ray diffraction after laser irradiation at 0.3, 2.0, and 3.0 W using either contact or noncontact handpieces. Controls received no laser irradiation. Melting, loss of porosity, and other surface alterations were observed on both types of implants, even with the lowest power setting. For the sterilization study, both types of implants were first sterilized by exposure to ethylene oxide and then contaminated with spores of B. subtilis. After laser irradiation, the implants were transferred to sterile growth medium and incubated. Laser irradiation did not sterilize either type of implant. The spore-contaminated implants in the control group were successfully sterilized with ethylene oxide.

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IN VITRO EVALUATION OF THE BIOCOMPATIBILITY OF CONTAMINATED IMPLANT SURFACES TREATED WITH AN ER:YAG LASER AND AN AIR POWDER SYSTEM

Matthias Kreisler, Wolfgang Kohnen, Ann-Babett Christoffers, Hermann Götz, Bernd Jansen, Heinz Duschner, Bernd d’Hoedt
Johannes Gutenberg-University Mainz, Mainz, Germany

Titanium platelets with a sand-blasted and acid-etched surface were coated with bovine serum albumin and incubated with a suspension of Porphyromonas gingivalis (ATCC 33277). Four groups with a total of 48 specimens were formed. Laser irradiation of the specimens (n = 12) was performed on a computer-controlled XY translation stage at pulse energy 60 mJ and frequency 10 pps. Twelve specimens were treated with an air powder system. After the respective treatment, human gingival fibroblasts were incubated on the specimens. The proliferation rate was determined by means of fluorescence activity of a redox indicator (Alamar Blue Assay) which is reduced by metabolic activity related to cellular growth. Proliferation was determined up to 72 h. Contaminated and nontreated as well as sterile specimens served as positive and negative controls. Proliferation activity was significantly (Mann-Whitney U-test, P < 0.05) reduced on contaminated and nontreated platelets when compared to sterile specimens. Both on laser as well as air powder-treated specimens, cell growth was not significantly different from that on sterile specimens. Air powder treatment led to microscopically visible alterations of the implant surface whereas laser-treated surfaces remained unchanged. Both air powder and Er:YAG laser irradiation have a good potential to remove cytotoxic bacterial components from implant surfaces. At the irradiation parameters investigated, the Er:YAG laser ensures a reliable decontamination of implants in vitro without altering surface morphology.

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RESEARCH ABSTRACTS

INFLUENCE OF AN ERBIUM, CHROMIUM-DOPED YTTRIUM, SCANDIUM, GALLIUM, AND GARNET (ER,Cr:YSGG) LASER ON THE REEVALUATION OF THE BIOCOMPATIBILITY OF CONTAMINATED TITANIUM IMPLANT SURFACES

Frank Schwarz, Enaas Nuesry, Katrin Bieling, Monika Herten, Jürgen Becker
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J Periodontal 2006;77(11):1820-1827

Background: The aim of the present study was to evaluate the influence of an erbium, chromium-doped yttrium, scandium, gallium, and garnet (Er,Cr:YSGG laser [ERCL]) on (1) the surface structure and biocompatibility of titanium implants and (2) the removal of plaque biofilms and reestablishment of the biocompatibility of contaminated titanium surfaces. Methods: Intraoral splints were used to collect an in vivo supragingival biofilm on sand-blasted and acid-etched titanium disks for 24 hours. ERCL was used at an energy output of 0.5, 1.0, 1.5, 2.0, and 2.5 W for the irradiation of (1) noncontaminated (20 and 25 Hz) and (2) plaque-contaminated (25 Hz) titanium disks. Unworn and untreated nonirradiated, sterile titanium disks served as untreated controls (UC). Specimens were incubated with SaOs-2 osteoblasts for 6 days. Treatment time, residual plaque biofilm (RPB) areas (%), mitochondrial cell activity (MA) (counts per second), and cell morphology/surface changes (scanning electron microscopy [SEM]) were assessed. Results: (1) ERCL using either 0.5, 1.0, 1.5, 2.0, or 2.5 W at both 20 and 25 Hz resulted in comparable mean MA values as measured in the UC group. A monolayer of flattened SaOs-2 cells showing complete cytoplasmatic extensions and lamellopodia was observed in both ERCL and UC groups. (2) Mean RPB areas decreased significantly with increasing energy settings (53.8 +/- 2.2 at 0.5 W to 9.8 +/- 6.2 at 2.5 W). However, mean MA values were significantly higher in the UC group. Conclusion: Within the limits of the present study, it was concluded that even though ERCL exhibited a high efficiency to remove plaque biofilms in an energy-dependent manner, it failed to reestablish the biocompatibility of contaminated titanium surfaces.

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BACTERICIDAL EFFICACY OF CARBON DIOXIDE LASER AGAINST BACTERIA-CONTAMINATED TITANIUM IMPLANT AND SUBSEQUENT CELLULAR ADHESION TO IRRADIATED AREA

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Niigata University, Niigata, Japan

Background and Objective: The aim of this study was to assess CO₂ laser ability to eliminate bacteria from titanium implant surfaces. The changes of the surface structure, the rise in temperature, and the damage of connective tissue cells after laser irradiation were also considered. Study Design/Materials and Methods: Streptococcus sanguis and Porphyromonas gingivalis on titanium discs were irradiated by an expanded beam of CO₂ laser. Surface alteration was observed by a light, and a scanning electron, microscope. Temperature was measured with a thermograph. Damage of fibroblastic (L-929) and osteoblastic (MC3T3-E1) cells outside the irradiation spot and adhesion of the cells to the irradiated area were also estimated. Results: All the organisms (108) of S. sanguis and P. gingivalis were killed by the irradiation at 286 J/cm² and 245 J/cm², respectively. Furthermore, laser irradiation did not cause surface alteration, rise of temperature, serious damage of connective tissue cells located outside the irradiation spot, or inhibition of cell adhesion to the irradiated area. Conclusion: CO₂ laser irradiation with expanded beam may be useful in removing bacterial contaminants from implant surface.

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Ana Trillouris, DDS, Private Practice, NY will present “Practical Caries Management in the Laser Dentistry Office”. Dr. Trillouris will describe how to successfully implement diagnostics and caries management into the laser dentistry office.

Tord Lundgren, Prof. of Periodontology, University of Florida at Gainesville, FL will in his presentation “Minimally Invasive Periodontal Treatment” shed light on the aspects of minimal invasive periodontal treatment (The Scandinavian School).
Peter Pang, DDS, Private Practice, Santa Rosa, CA will present an overview and clinical aspects of “Lasers in periodontal treatment”.
Jeanne Godett, RDH, Sacramento, CA will present an additional counterpoint to these two presentations in the Hygiene Forum.

Brian Houston, DDS, Private Practice, Prosthodontist will emphasize the esthetic aspects and rules for placing implants from a Prosthodontist’s clinical view in “The Esthetics of Implant Placement – The Prosthodontic View”.
Stephen P.A. Parker, BDS, LDS RCS, Private Practice, United Kingdom will present “Lasers in Implantology – placing, uncovering, and treatment of periimplantitis”.

Adam Stabholz, Prof. of Endodontics, University of Jerusalem will take a critical look at “The Practical Use of Lasers in Endodontics” and will give guidance for the clinical use of lasers in endodontics.

Partial listing; subject to change

Social Events and Tours
Visit http://laserdentistry.org/ald2008/ for details on all tours

- **Wednesday, April 9:**
  - 7:30 pm – 9:00 pm Welcome Reception and Exhibits
  - Preview
  - Fees: None

- **Thursday, April 10:**
  - 8:30 am - 3:00 pm Wild Animal Park
  - Fees: $95 adults (12+)
  - $75 children (3-11)

- **Friday, April 11:**
  - 10:00 am - 1:30 pm Luncheon at the famous Hotel del Coronado
  - Fees: $68.00 per person

- **Saturday, April 12:**
  - 9:00 am - 2:00 pm San Diego Trolley, Amphibious Seal Vehicle Tour of San Diego, the Harbor, & Old Town Mission and Shopping
  - Fees: $75.00 per person

- **Saturday, April 12:**
  - 7:00 pm – midnight President’s Awards Ceremony, Dinner Dance and Rock n Roll Party
  - Fees: Included in Dentist and Auxiliary registration categories. $150 for other registration categories or guests.

- **Friday, April 11:**
  - 3:00 pm – 7:30 pm ALD2008 Sailing Regatta
  - (34 footers with captain)
  - Fees: $105.00 per person

Advance reservations required for these events. Subject to change.

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- **Introductory to Lasers Course**
  - Wednesday, April 9, 2008 – 7:30am – 9:30pm

- **Standard Proficiency**
  - Wednesday, April 9, 2008 – 7:30am – 9:30pm
  - Thursday, April 10, 2008 – 1:00pm – 6:00pm

- **Advanced Proficiency**
  - Wednesday, April 9, 2008 – 7:30am – 6:00pm

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